

THE
ELEMENTS
OF
NAVAL ARCHITECTURE:
OR, A
PRACTICAL TREATISE
ON
SHIP-BUILDING.
LATELY PUBLISHED AT PARIS.

By M. DUHAMEL du MONCEAU,
Inspector General of the Marine to his most Christian Majesty, Member of the Royal Academy of Sciences at Paris, and Fellow of the Royal Society at London.

CAREFULLY ABRIDGED
By MUNGO MURRAY.

L O N D O N:

Printed by D. HENRY and R. CAVE, at St JOHN'S GATE, for the AUTHOR, and Sold by the Bookfellers in Town and Country.

M,DCC,LIV.

THE

EDMUND

OF

NAVAL ARCHITECTURE

CHAPTER II

OF THE PRINCIPLES OF THE

PRACTICAL DESIGN

OF THE

SHIP-BUILDING

BY

JOHN ROBERTSON

OF THE

NAVY

OF GREAT BRITAIN

CHAPTER III

OF THE

SHIP-BUILDING

OF THE

NAVY

OF GREAT BRITAIN

BY

JOHN ROBERTSON

OF THE

C O N T E N T S.

CHAP. I.

G eneral Proportions for Building	—	Pages. 1
--	---	-------------

CHAP. II.

Of the Scantlings and Dimensions of the principal Pieces of Timber in a Ship	— — —	10
---	-------	----

CHAP. III.

A method to lay down a 70 Gun Ship upon the Plane of Elevation		15
--	--	----

CHAP. IV.

To lay down the Frames upon Plane of Projection		21
---	--	----

CHAP. V.

Of the Projections on the horizontal Planes, and of the Water and Ribband Lines on the Plane of Elevation, and that of the Projection		33
--	--	----

CHAP. VI.

Another Method of laying down the Horizontal Plane, and the Plane of Projection	— — —	39
--	-------	----

CHAP. VII.

Ganeral Remarks on Ship Building	—	46
----------------------------------	---	----

CHAP. VIII.

To know by the draught how high a Ship will carry her Guns out of the Water	— — —	49
--	-------	----

CHAP. IX.

A Method to calculate the Resistance of the Water upon the fore Part of the Ship	— — —	57
---	-------	----

CONTENTS

CHAPTER I

General Proportions for Building

CHAPTER II

Of the Strength and Dimensions of the principal Parts of a Ship in a Ship

CHAPTER III

CHAPTER IV

CHAPTER V

CHAPTER VI

CHAPTER VII

CHAPTER VIII

CHAPTER IX

A

PRACTICAL TREATISE

ON

SHIP-BUILDING.

C H A P. I.

General Proportions for Building:

N AVAL Architecture may be divided into three principal parts.

I. To give the ship such a figure or exterior form, as may suit the service she is designed for.

II. To find the true form of all the pieces of timber that shall be necessary to compose such a solid.

III. To make proper accommodations for guns, ammunition, provisions, and apartments for all the officers, and likewise for the cargo.

We shall at present only treat of the first of these, namely the exterior figure, and consider it first, as it regards the bottom, that is, the part which lies under water, and may be called the quick-work ; or secondly. the part which is above water, and may be called the dead-work.

In order to give a proper figure to the bottom, all the qualities which are necessary to make a ship answer the service for which she is design'd, should be considered. A ship of war should carry her lower tier of guns four or five feet out of the water. A ship for the merchants service should stow the cargo well, and both of them should be made to go well, carry a good sail, steer well, and lie too easily in the sea.

Some

Some eminent geometricians have endeavoured to find the form of a solid which may best answer all these qualities, and meet with the least resistance in dividing the fluid through which it is to pass; but have not been able to reduce their theory to practice by reason of the different positions a ship is obliged to be in when under sail. The ship-builders despairing to establish this point by mathematical rules, have applied themselves wholly to their own observations and experience, which may indeed supply the deficiencies of art, but though they may thereby discover that a ship has several bad qualities, it will not be easy to determine where the fault lies; for it may be owing to the rigging; and though the fault be not there, yet they cannot be certain in what particular part of the body it is. If their observations be assisted by principles drawn from theory, it will conduce very much to attain their end.

As there have been several ships built which have seemed to answer all the services for which they have been designed, some builders have made it their principal study to copy ships which have gained the applause of the seamen. This method they very improperly call the principal rule which should be observed in building. Now, as the bodies of ships are very different from one another, so there are, by this means, as many different methods used; some chusing one, and some another for a standard. But it must be observed, that even though it were possible to find such a body as should give intire satisfaction, and have all the good qualities that should be necessary to answer the services proposed, yet this could by no means be established as a standard by which other ships of different dimensions may be built. For admitting we have a first rate of 100 guns, which by experience has been found to be a very good ship in all respects, yet we should find ourselves very much deceived, if we should build a ship of 20 guns by making all the parts have the same proportion to one another that they have in that of 100 guns.

The first thing to be done in order to lay down the draught of a ship is to determine the length, which should be either on the lower gun deck, or at the load-water line; for there must be great care taken that there is a sufficient space betwixt the ports. This will oblige us first to fix the number and dimensions of the ports, the distance of the aftermost port from the transom, and of the foremost from the stem, and the distance betwixt the ports. This article may be determined by the following tables:

A Table

A Table of the Number of Ports on each Side of a Ship, according to the Number of Guns, and the Weight of the Shot:

A Ship of 112 Guns.			A Ship of 102 Guns.			A Ship of 74 Guns.		
Decks	Ports	Shot	Decks	Ports	Shot	Decks	Ports	Shot
1	15	48 or 36	1	14	36	1	13	36
2	16	24	2	15	18		14	
3	15	12	3	14	12	2	14	18
Quarter	5	8	Quarter	13	6		15	
Forecastle	3	8	Forecastle			Quarter	8	8
Poop	2	4	Poop			Forecastle	8	
						Poop	2	4
A Ship of 64 Guns.			A Ship of 58 Guns.			The Tiger.		
Decks	Ports	Shot	Decks	Ports	Shot	Decks	Ports	Shot
1	12	24	1	12	18	1	11	18
	13		2	13	12	2	12	8
2	13	12	Quarter	4	4	Quarter	3	6
	14		Forecastle			Forecastle	2	4
Quarter	7	6						
Forecastle	5							
A Ship of 50 Guns.			A Frigate of 46 Guns.			A Frigate of 32 Guns.		
Decks	Ports	Shot	Decks	Ports	Shot	Decks	Ports	Shot
1	11	18	1	11	12	1	10	6
2	12	12	2	12	8	Quarter	6	4
Quarter	2	4				Forecastle		
A Frigate of 32 Guns.			A Frigate of 32 Guns.			A Frigate of 28 Guns.		
Decks	Ports	Shot	Decks	Ports	Shot	Decks	Ports	Shot
1	4	8	1	10	8	1	3	8
2	10	6	2	6	6	2	10	4
Quarter	2	4				Quarter	1	4
Forecastle								
A Frigate of 24 Guns.			A Frigate of 22 Guns.			Frigates of 20 Guns have 10 Ports on each side on one Deck. Shot 6 lb.		
Decks	Ports	Shot	Decks	Ports	Shot			
1	10	6	1	9	6			
Quarter	2	4	Quarter	2	4			

Vessels of 16 guns have 8 ports on one deck, the guns to carry 4 lb. shot.

Vessels of 12 guns have 6 ports on one deck, the guns to carry 4 lb. shot.

A Table of the Dimensions of the Ports and Height of their Sells, according to the Weight of the Shot.

Shot lb.	Hei. and brea. of ports.						Height of the ports						Sells		Quarter- Deck and Forecastle
	f.	in.	f.	in.	f.	in.	1st Deck	2d Deck	3d Deck	4th Deck	5th Deck	6th Deck	7th Deck	8th Deck	
48	2	9	3	0	or	3	2	f.	in.	f.	in.				
36	2	8	3	0	or	3	1	2	2						
24	2	5	2	8	or	2	10	2	1	2	0				
18	2	4	2	7	or	2	8	1	11	1	9				
12	2	2	2	4	or	2	6	1	10	1	8	1	7		
8	1	9	1	11	or	2	3	1	8	1	6				1 5
6	1	6	1	8	or	1	11	1	7	1	6				1 5
4	1	4	1	6	or	1	9	1	5						1 3

A Table of the Number, Dimensions and Distances betwixt the Ports on the lower Deck; also the Distance betwixt the foremost Port and the Stem, betwixt the Aftmost and the Sternpost.

Ships Names.	N ^o of Ports	Breadth of Ports		Dist. betw. Ports		Foremost from Stem		Aftmost from Post		Length on L. Deck
Amiable	13	2	8	7	6	13	4	9	0	147
Invincible	13	2	8	7	4	12	4	9	0	144
Achilles	12	2	8	7	8	18	2	10	6	145
Toulouse	12	2	8	7	6	17	4	9	2	141
Ardent, 64 guns	12	2	8	7	6	17	0	9	2	140 8
Fleurion, 64 guns	12	2	8	7	8	18	10	10	6	145 8
Dauphin Royal 74 guns	13	2	10	7	7	18	2	10	0	156

Note, An inch *French* measure is equal to $1\frac{1}{8}$ inch *English*, and is divided into twelve parts called lines, which are divided into twelve parts, called points.

The next thing to be done is to establish the breadth by the midship beam; the builders are pretty much divided in proportioning this to the length. Most of them conform to dimensions taken from ships of the same burthen, and designed for the same service.

After these two dimensions are determined, the depth of the hold must be fixed, which in most ships is half the breadth; but the form of the body should be considered; for a flat floor will require less hold than a sharp one. The distances likewise between the decks must be determined. The following table may be very useful towards ascertaining the three aforesaid dimensions,

A Table

A Table of the Length, Breadth, and Depth in Hold of the following Ships.

Ships Names	Guns	Length at load-water line		Breadth		Depth in the Hold	
		feet	in.	f.	in.	f.	in.
Monarque	74	165		43		20	6
Intrepide	74	165		43		20	6
Alcide	64	149		40	6	19	4
Renommée	30	120		31	8	15	7
Palme	12	85		22	6	10	5
Soleil Royal	80	182		48		23	
Formidable	80	178		44	10	21	10
Tonnant	80	168		46		23	
Sceptre	74	165		43		20	6
Superbe	74	153	6	42	8	21	
Esperance	74	154		42		21	
Magnifique	74	165		43		20	6
Northumberland	68	149		40		20	
Lis	64	149		40		19	
Hercule	64	149		40	6	19	4
Protee	64	150		40	6	19	4
Illustre	64	150		40	8	20	
Opinatre	64	150		40	4	19	5
Dragon	64	149		40		19	
Leopard	64	146		39	6	18	6
St Laurent	60	145		39	4	18	8
Amphion	50	145		39		18	
Amazon	44	118					
Brillant	50	135		35			
Arc-en-Ciel	50	135		37		17	9
Tigre	52	131		37		17	
Alcion	50	132		35	4	18	
Aquilon	46	127		34		17	
Junon	46	136		36	6	16	6
Favorite	36	127		33		14	
Anglesea	32	121	8	33	6	16	
Serenne	30	118		31	8	15	9
Emeraude	28	118		31	8	16	
Galatée	24	110		29		14	6
Mutine	24	110		29		14	6
Cumberland	24	102		26		13	
Marthal Saxe	22	100		27		14	
Anemone	12	84		22		9	

Ships Names	Guns	Length	Breadth		Depth	
		feet	f.	in.	f.	in.
Amarante	12	84	22		9	
Elizabeth	64	143	38	4	18	
Brave	80	172	44		21	
Florissant	74	165	45		22	6
Couronne	74	167	44		22	7
Hardi	64	149	40	6	20	9
Aigle	50	144	39		19	6
Hermione	26	126	33	8	13	8
Juste	70	151	42		21	
Triponne	26	114	31	8		
Panthere	20	108	28	6		
Badine	6	66	18	4		

We may then proceed to fix the length of the keel, which will oblige us to determine the rake of the stem and , for which the builders have given us no invariable rule, they very much divided in their opinions ; for where some have given rake of 18 or 20 feet, others have given none at all. The height of the stem and wing-transom must also be determined, which may be regulated by the decks.

The difference betwixt the draught of water abaft and that afore, should likewise be considered ; for though some imagine that when a ship is loaded her keel should be parallel to the surface of the water, yet in many cases it will be found necessary that the keel abaft should be deeper in the water than it is afore. This will give the rudder more power, and thereby contribute to make a ship steer well ; but this difference of the draught of water is intirely arbitrary ; for in large ships some have given five, whereas others have given but three, or even two feet of difference. Though I could not procure the true difference of the draught of water of many ships of war, yet I am assured that the following are pretty exact.

The Difference of the Draught of Water in the following Ships.

	feet	in.		feet	in.
Northumberland	1	2	Panthere	1	4
Auguste	1	6	Couronne	2	1
Aloze	1	0	Triponne	2	
Hermione	2	0	Renommée	1	4
Amazone	1	6	Tigre	3	2
Badine	0	10	Intrepide	2	3
Palme	1	4	Alcide	2	0

The

The length of the wing transom must also be determined; some make it $\frac{2}{3}$ of the main breadth; but this is likewise arbitrary, the broader a ship is abaft, the more room there will be for accommodations for the officers; but this will be disadvantageous to her sailing upon a wind.

The following Examples will be sufficient to fix the Length of the Wing transom for any Ship,

For a ship of 110 guns, $\frac{2}{3}$ of the main breadth, and 3 lines more to every foot.

102 guns, $\frac{2}{3}$ of the main breadth, and 8 inches more.

82 guns, $\frac{2}{3}$ of ditto.

74 guns, 7 inches, 9 lines for every foot in breadth.

62 guns, 7 inches, 8 lines for ditto.

56 guns, 7 inches, 7 lines, 3 points for ditto.

50 guns, 7 inches, 6 lines, 6 points for ditto.

46 guns, 7 inches, 6 lines for ditto.

32 guns, 7 inches, $5\frac{1}{2}$ lines for ditto.

For a frigate of 22 guns, 7 inches 4 lines.

12 guns, 7 inches.

Some, without regarding these proportions, make the wing transoms of the first and second rates two thirds of the breadth, and for all the rest one foot less.

After these dimensions are determined, the timbers may be considered which form the sides of the ship. A frame of timbers is composed of one floor timber, two or three futtocks and a top timber on each side: All these being united together, and secured by cross-bars, form a circular inclosure, that which incloses the greatest space is called the midship frame: The curve of this frame is inverted at the lower part, so that the floor timber will be somewhat hollow in the middle, whereby the ends will form a very obtuse angle; but this angle decreases the farther the frames are removed from the midships, in such a manner, that the foremost and aftermost will become very sharp, and form a very acute angle. These floor timbers are called crutches.

The builders seem to agree nearly as to the length of the midship floor timber, making it generally half the length of the main beam; but they differ very much about the rising of it, some chusing a flat and others a sharp floor. And if we consider the advantages and disadvantages that attend the one and the other, we shall not be much surprized to find them so much divided upon this article; for it is certain, the more rising a ship has, she will hold the better wind, but then this will occasion her to draw more water, which will be sometimes attended with very great inconveniencies.

A Table

A Table of the rising of the Midship Floor Timbers.

Guns	f.	in.	lines		Guns	f.	in.	lines	
110	0	0	10	} to every foot in length.	56	0	1	4	} to every foot in length.
102	0	0	$10\frac{1}{2}$		32	0	1	4	
86	0	1	0		28	0	1	4	
74	0	1	0		22	0	1	6	
62	0	1	$0\frac{1}{2}$		16	0	1	6	

Note, *What we have here rendered the rising of the floor timbers, the author calls the Aculement, and makes a distinction betwixt it and the rising, which we shall see when we come to form the frames.*

They differ as much in determining the station of the midship frame, some placing it before, others at the middle of the ship; others again have two floor timbers of equal length, and rising, one of which is placed exactly in the middle, or the breadth of the timber before the middle, and the other at a proper distance before it. Those who place it before alledge that if a ship is full forward, after she has once opened a column of water, she will afterwards meet with no resistance, and the water will easily unite abaft, and by that means force the ship a-head, and have more power on the rudder the farther it is from the centre of gravity; and besides this comes nearest the form of fishes, which should seem to be the most advantageous for dividing fluids.

Those who would have it placed in midships say, that by that means the water-lines forward will be easier, and of consequence properer for dividing fluids; and that there will be space enough betwixt it and the rudder for forming very fair water-lines, so that the water will easily unite at the rudder; and besides it will be easier by this means to balance the fore body and after body; and in general the building will by this means be very much facilitated: so that, in my opinion, it will be properest to place it very near the middle, though it is the general practice to place it before it.

After the rising of the midship floor timber is determined, we may then proceed to fix the height of the rising line of the floor abaft on the post, and afore upon the stem.

Now, as all ships are narrower abaft and afore, than in midships, the other floor timbers will of consequence be shorter and have a greater rising, which will be still increasing till it ends on the post and stem. There are several different methods used by the builders to settle the height of this line. Some imagine, that by narrowing the floor abaft, which will occasion the rising line to be high upon the post, the ship will

will thereby steer better, and besides, the water which is opened by the midship frame will then have a greater pressure upon the after part of the ship, and thereby contribute to her sailing: Yet these arguments are of very little weight; for if we only consider the steerage, it is certain, that the higher the rising line is carried abaft, and the narrower a ship is, the water will have the easier passage, and more power upon the rudder. But then we shall thereby run the risk of falling into two great inconveniencies; for by this means we take away the buttock, which is the only thing we have to support all the weight of the after part of the ship; neither shall we be able to give a proper balance betwixt the fore and after part, and when the fore and after parts are not duly balanced, it will occasion a ship to pitch very hard, and be in danger of being frequently pooped by the sea when it runs high. To prevent these inconveniencies it will be proper to give all ships, especially the large sort, a full buttock. As to the height of the rising line afore, it should be determined by the form of the water lines; but before this can be done, the timbers must be formed.

Note, What we have rendered the rising line of the floor, our author calls les façons, which, he says, is the increase of the acculement, the extreme points of which upon the perpendicular of the stem and post, are now to be determined.

The height of the lower deck is the next thing to be considered: It is determined in midships by the depth of the hold, and some builders make it no higher at the stem; but they raise it abaft more than it is in midships, as much as the load-water mark abaft exceeds that afore. As to the height betwixt decks, it is altogether arbitrary, and must be determined by the rate of the ship, and the service that she is designed for.

We come now to consider the upper works, or all that is above water, called the dead-work: And here the ship must be narrower, so that all the weight that lies above the load-water line will thereby be brought nearer the middle of the ship; by which means she will strain less by working the guns, and the main sail will be easier trimmed when the shrouds do not spread so much. But though these advantages are gained by narrowing a ship above water, great care must be taken not to narrow her too much, for there must be sufficient room upon the upper deck for the guns to recoil. The security of the masts should likewise be considered, which requires sufficient breadth to spread the shrouds, though this may be assisted by enlarging the breadth of the channels.

C H A P. II.

Of the Scantlings and Dimensions of the principal Pieces of Timber in a Ship.

ALTHOUGH it is not my intention, as I observed in the beginning of the last chapter, to treat of all the pieces that compose the ship, yet I think it necessary to say something of the principal pieces. I shall therefore in the following plate lay down each piece by itself, by which means we shall see the length of the scarphs, and in what manner they are to be joined together.

Explanation of Plate I.

I.

A. The keel in four pieces, to be well bolted together, and clinched.

II.

I. The fore foot, one end of which is scarphed to the fore end of the keel, of which it is a part, and the other end makes a part of the stem, to which it is scarphed.

III.

u u. Two pieces of dead wood, one afore and the other abaft, fayed upon the keel.

IV.

C C. The stem in two pieces, to be scarphed together.

V.

E E. The apron in two pieces, to be scarphed together, and fayed on the inside of the stem, to support the scarph of the stem; for which purpose the scarph of the apron must be clear from that of the stem.

VI.

o. The stemson in two pieces, to support the scarph of the apron.
o. The false post, which is fayed to the fore part of the post.

VII.

B. The stern post: It is tenanted into the keel, to which it is fastened with a knee.

D. The

VIII.

D. The back of the post, which is likewise tenanted into the keel and well bolted to the post; the design of it is to give sufficient breadth to the post, which seldom can be got broad enough in one piece.

IX.

F. The knee which fasteneth the post to the keel.

X.

N. The wing transom. It is fayed across the stern post, and bolted to the head of it: The fashion pieces are fastened to the ends of it; underneath this and parallel to it is the deck transom.

XI.

OO. Two transoms fastened to the stern post and fashion pieces, in the same manner as the wing transom.

XII.

P. The transom knee, which fasteneth it to the ship's side.

XIII.

Q. The fashion piece, of which there is one on each side: Their heels are fastened to the stern post at the height of the floor ribbands, and their heads are fastened to the wing transom.

XIV.

T. A floor timber. It is laid across the keel, to which it is fastened by a bolt through the middle.

XV.

K. The lower futtock.

XVI.

T T T T T. 2d, 3d, 4th futtocks and top timbers. These shew the proper length and scarph of the timbers in midships frame.

XVII.

U U. Riders. These are fayed in the inside of the ship, and consist of floor and futtock riders.

C 2

Z. The

XVIII.

Z. The keelson. This is made of two or three large pieces of timber scarphed together in the same manner as the keel. It is placed over the middle of the floor timbers, and scored about an inch and a half down upon each of them.

XIX.

R, S. Breast-hooks. These are fayed in the inside to the stem, and to the bow on each side of it, to which they are fastened with proper bolts. There are generally four or five in the form of R in the hold, one in the form of S into which the lower deck planks are rabbited; there is one right under the hawse holes, and another under the second deck.

XX.

X, Y, Z. are thick planks which are fayed in the inside, and stretch fore and aft to strengthen the scarphings of the timbers.

XXI.

Z. are thick planks in the inside, called clamps, which support the ends of the beams.

XXII.

15, 15, 15, 15, 15, are the wales. They are planks broader and thicker than the rest, which are fastened to the outside of the ship in the wake of the decks. We shall have occasion in another place to show how they are laid down in a draught. As to the plank below the wale to the keel, and above it to the top of the side, we refer to the section of one half of the midship frame, as laid down in the plate.

XXIII.

d, d, d, d, d, d, are knees. These are crooked pieces of timber consisting of two arms which form an angle, either within or without a square, or exactly square; their use is to fasten any two pieces together, as the beams to the ship sides.

XXIV.

19. The rudder. This is joined to the stern post by the rudder irons, upon which it turns round in the googings which are fastened upon the stern post for that purpose. There is a mortise cut out of the head of it,

it, into which a long bar is fitted, called the tiller, by which the rudder is turned from one side to the other.

XXV.

23. The cat heads. These are two large pieces of square timber, one on each side of the bowsprit. They project out before the bow, in order to keep the anchor clear of the ship, which is hove up by a rope called the cat fall, that passes through shivers in the outer end of the cat-head: Their inner ends are fastened upon the forecastle.

XXVI.

m, m, i, i, i , are the several pieces which compose the knee of the head; the lower part m is fayed to the stem, the heel of it is scarphed to the head of the forefoot; it is fasten'd to the bows by two knees called cheeks, in the form of f , and to the stem by a knee call'd a standard, in the form of K .

XXVII.

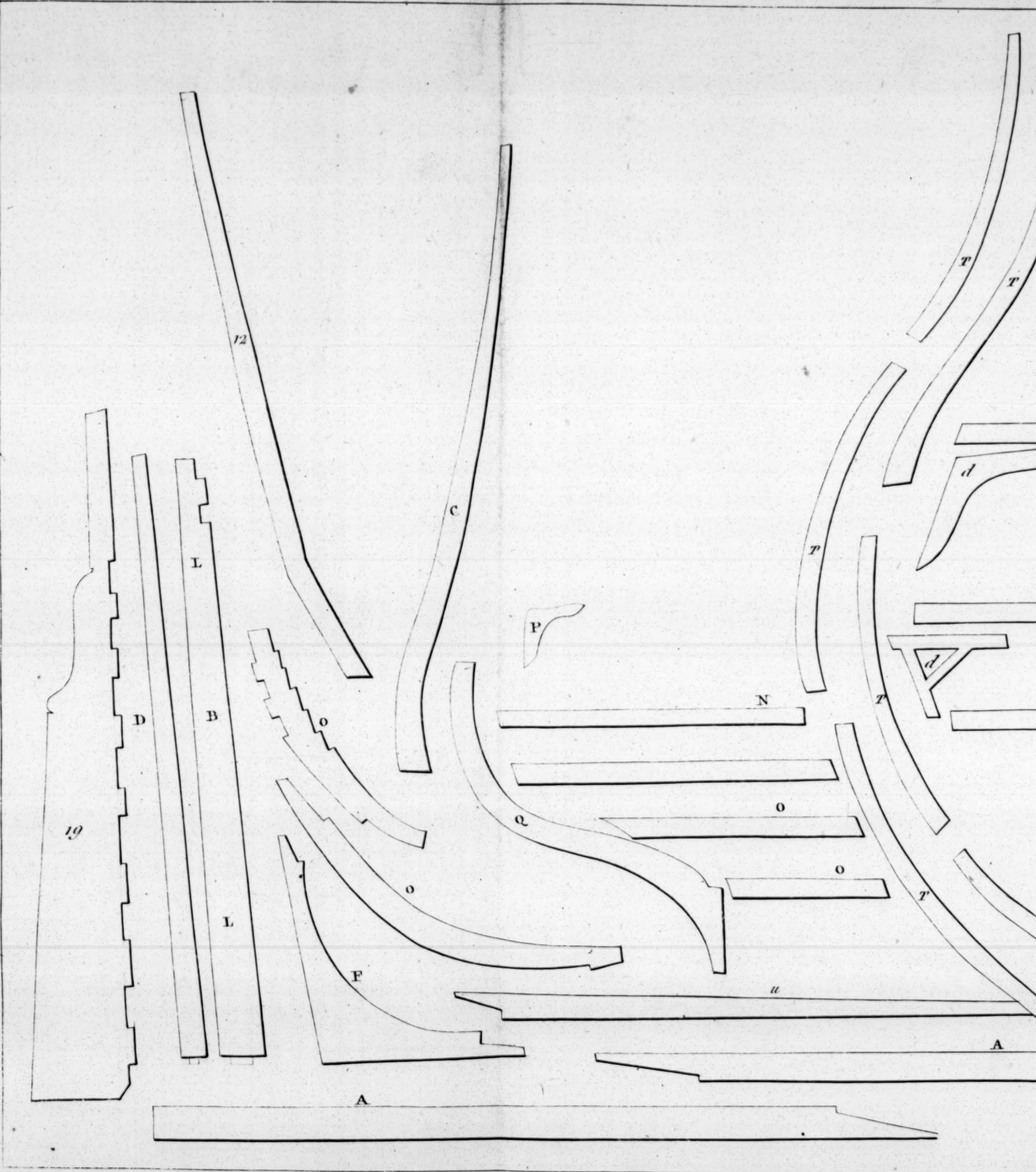
Beams &c, $a, X Y$, are large pieces of timber which support the planks of each deck.

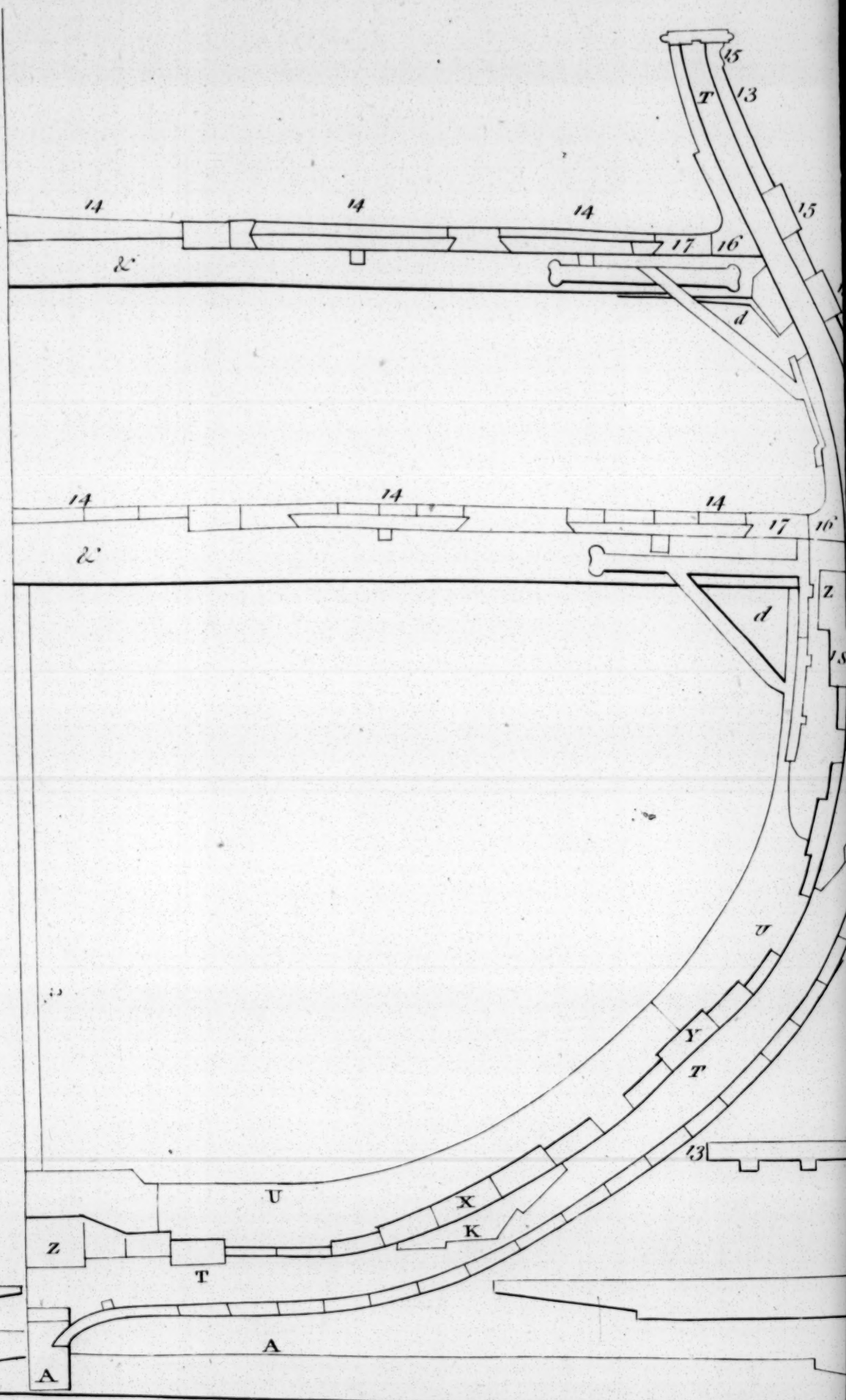
Having thus explained all the pieces in the plate, we shall in the following table give their scantlings.

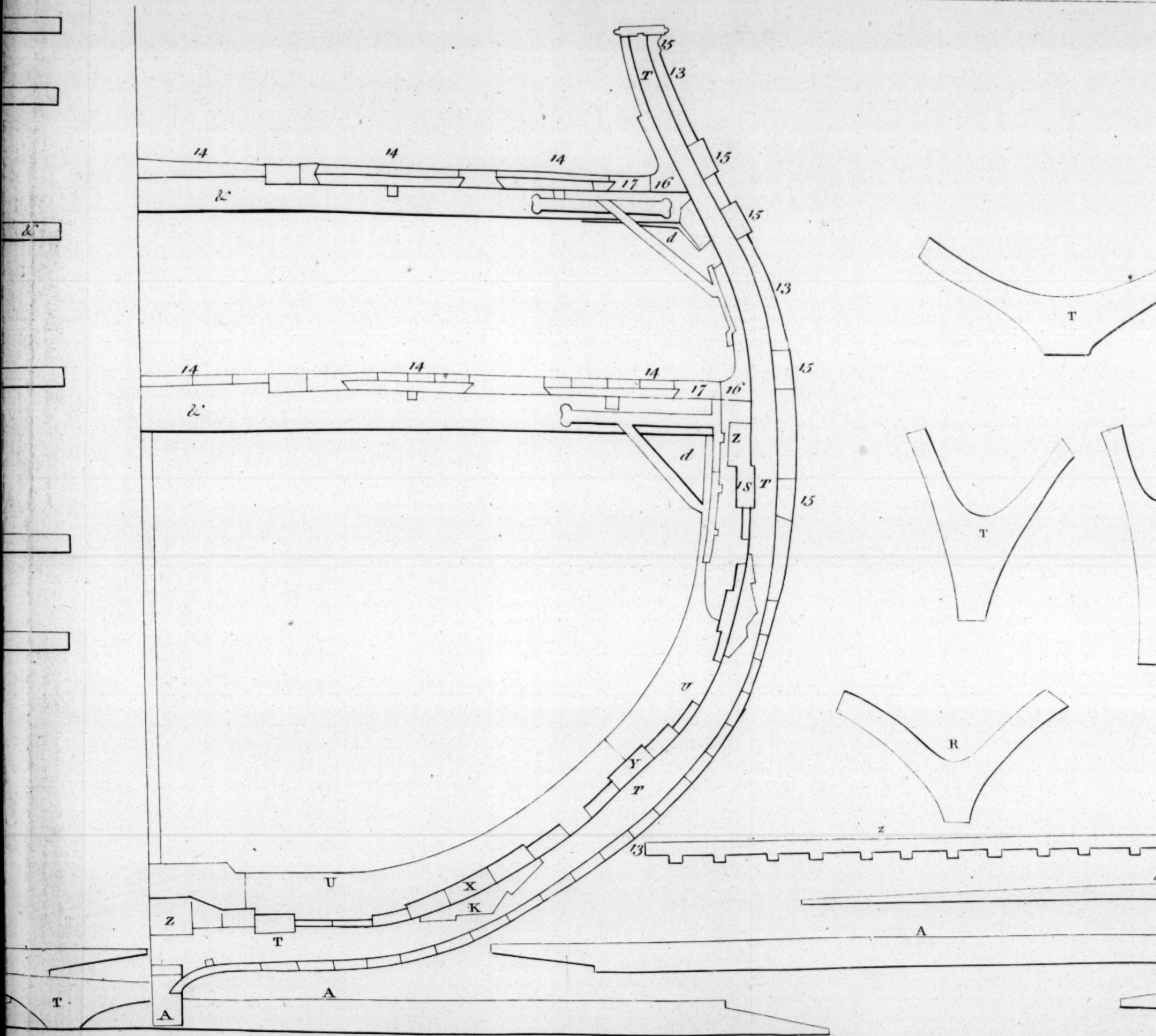
The

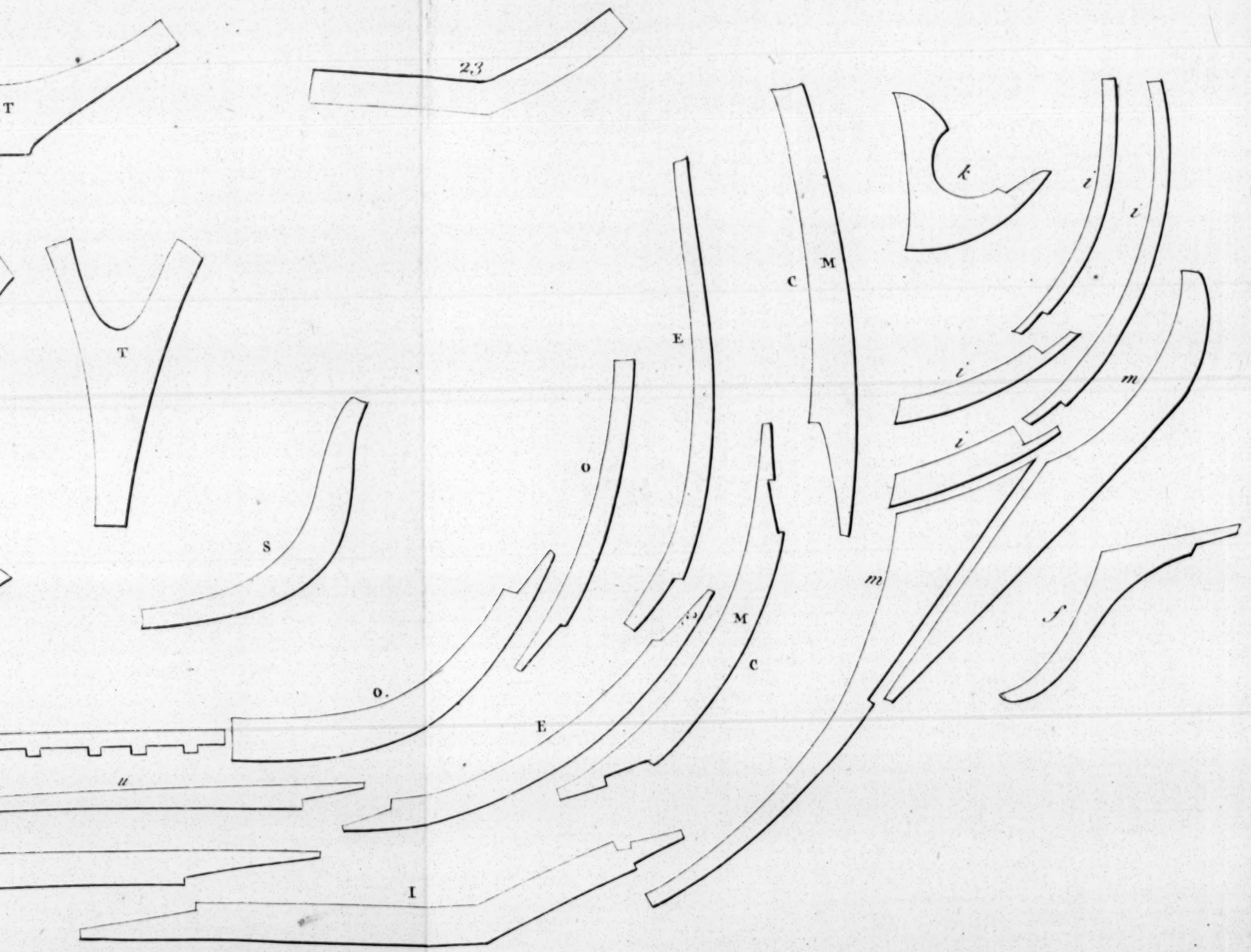
**BREADTH of the SHIPS
LENGTH of the SHIPS**

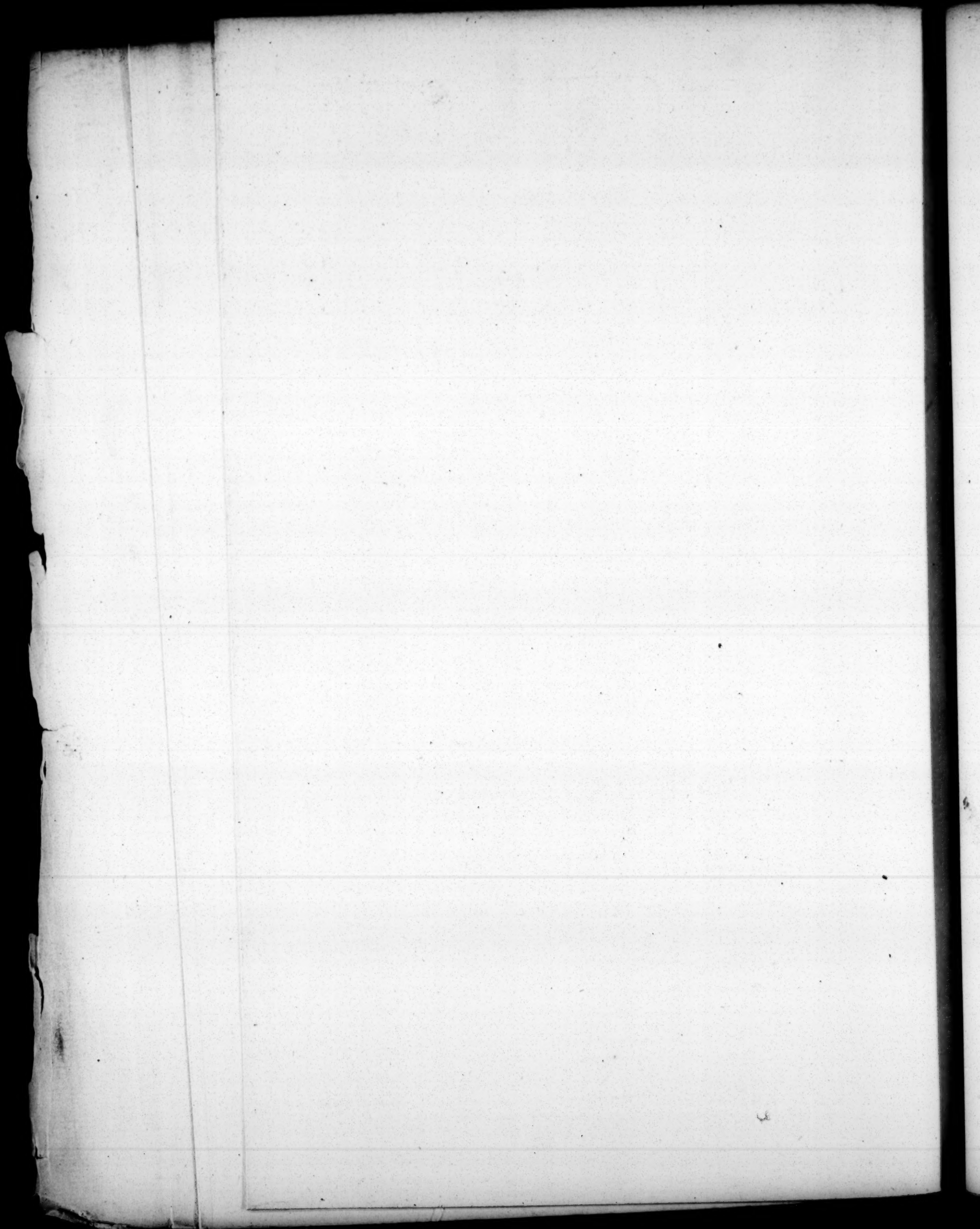
Note, The Scantlings of the Knees moulded is $\frac{2}{3}$ from the Throat.











C H A P. III.

A Method to lay down a 70 Gun Ship upon the Plane of Elevation.

THE Dimensions we have given of the principal parts of a ship of each class collected from the practice of different builders, which many have so great a regard to, as not to vary from them in the minutest article, we think only to be so far observed, as they shall produce such a form as the service the ship is designed for, shall require, agreeable to mathematical principles.

We shall now illustrate what has been said on that head by drawing a ship from these dimensions. But it will be first necessary to observe, that the builders make use of three different planes for one ship; 1st, the plane of elevation, in which the whole length is laid down according to a side view; 2d, The plane of the projection, which some call a vertical plane of the timbers, because it gives us an end view of the form of all the timbers, before the plank is put on. 3d, The horizontal plane, upon which are described all the curves that are formed by sections of the body parallel to the horizon, which must be considered as well as those vertical sections which form the curves of the timbers. We may likewise form the curves of the ribbands upon this plane, which will be of great use in proving whether the form we give the timbers will produce a fair side.

It is indifferent with which of these we begin, though that of the elevation seems most commodious. But first of all it will be very proper to draw out a list of all the dimensions of the vessel we are to build, so that we may have a view of the whole design.

This ship then is to have two tier of guns, so there must be two decks quite fore and aft, likewise a quarter deck as far as the main mast, a fore-castle 33 feet long, and a poop to the mizen mast.

There are to be 13 ports of a side on the lower deck, the guns to carry 24 lb. shot; 14 ports on each side upon the upper deck, the guns to carry 18 lb shot; on the quarter deck 4 guns, and on the fore-castle 2 guns of 8 lb. shot on each side, and 2 of 4 lb. on each side on the poop.

Ports

	feet	in.	l.
Ports on the lower deck fore and aft	2	10	
Distance betwixt the ports	7	9	
Aftermost port from the post	9	3	
Foremost from the stem	17	2	
Height of the fells, including the lower deck planks	2	5	
Ports up and down on the lower deck	2	7	
Distance from the upper side of the lower deck beam to the upper side of the upper deck beams	6	11	
Rising of the second deck abaft		11	
Second deck ports up and down	2	4	
Second deck ports fore and aft	2	6	
Height of the fells from the deck line	1	11	6
Distance betwixt the second deck and quarter deck from plank to plank	6	6	
Quarter deck ports up and down	1	10	
Quarter deck ports fore and aft	2		
Height of the fells	1	4	
Distance betwixt the quarter deck and poop	6	2	
Ports on the poop fore and aft	1	10	
Height of the fells	1	0	
Length from rabbit to rabbit on the gun deck	156	3	
Extreme breadth	42		
Depth in the hold below the plank	21	0	0
Rising of the lower deck abaft, not including the difference of the draught of water	2	11	6
Height of the stem	31	9	3
Height of the post	31	7	9
Rake of the stem	15	7	2
Rake of the post	3	1	5
Length by the keel	139	6	10
Depth of the keel	1	7	3
Length of the wing transom	27		
Length of the midship floor timber	21		
Rising of ditto	1	9	
Difference of the draught of water abaft more than afore	3	2	0
Height of the rising line of the floor abaft	13	6	0
Height of the rising line of the floor afore	5	7	5

I would advise young beginners in the art of drawing to conform exactly to these dimensions, which we have here given for an example, and

and observe all the particular directions which we shall give in laying down a ship of 70 guns; for they must begin by making themselves acquainted with the terms, and thereby gain a general idea of the whole design. After finishing this draught, they may then proceed to another of a different rate, and as we have given the principal dimensions of several good ships, they may chuse such a one as will best answer their design.

Plate II. Fig I.] 1st. Provide a scale of equal parts properly divided into feet and inches, adapted to the intended length of the draught, and draw the line A B, which make 156 feet 3 inches for the length of the gun deck, from the rabbet of the stem to that of the post.

To find the length on the gun deck, multiply 13, the } f. in. l.
number of ports, by 2 f. 10 in. the dimensions of each port } 36 10 0
fore and aft, the product is

Again multiply 7 f. 9 in. the distance betwixt the ports, by } 93 0 0
12, the number of spaces, the product is

Aftmost port before the post	9	3	0
Foremost abaft the stem	17	2	0
Length on the gun deck	156	3	0

2dly, Draw the line CD equal and parallel to AB, let 21 feet, the half of the main breadth, be the distance betwixt them, and erect the perpendiculars CF and DZ.

3dly, Set off 3 feet 2 inches, the difference of the draught of water, from B to G, and draw the line AG, which will give the position of the lower side of the keel. From A set off 1 foot 7 inches 3 lines, the depth of the keel, as in the table of scantlings, to K, and draw the line KI parallel to AG, which will be the upper side of the keel.

4thly, Set off 1 foot 3 inches 3 lines, the breadth of the stem from G to M, and draw the dotted line MN parallel to GZ. From G set off 15 feet 7 inches 2 lines, the rake of the stem, to O.

5thly, Set up 31 feet 9 inches 3 lines, the height of the stem from G to P. With the radius IP describe the arch PO, which will be the fore side of the stem, and from the same center describe another arch within the former, which will give the inside of the stem, and another arch for the rabbet may be described four inches before the inside of the stem.

6thly, Set up 25 feet 1 inch from K to L for the height of the gun deck abaft, and 21 feet 6 inches from I to e, for the height afore.

7thly, Set up 2 feet 5 inches, the height of the port-fells from L to a, which will give the upper side of the wing transom; from which set up
D 2 feet

2 feet 7 inches, the height of the ports; also 1 foot for the depth, and 6 inches 9 lines for the round of the helm port transom, to the point F, which will be the height of the post; so KF will be 31 feet 7 inches 9 lines. From K set off 3 feet 1 inch 5 lines to *f*, for the rake of the post, and draw the line F*f* for the aft side of the post. From *f* to *b* set off the depth of the keel, and draw the line *bd* for the fore side of the post, making F*d* $\frac{3}{4}$ of *fb*, so shall *fO* be the whole length of the keel.

The builders are very much divided about assigning a proper place for the midship frame, for which the following method may be used:

Divide the line CD into two equal parts, then take 5 feet 6 inches 10 lines, that is $\frac{1}{8}$ part of 156 feet 3 inches, the length of the gun deck: Set off this before the middle of the line CD, which will give the point F the station of the midship frame. Set up 21 feet from F to Z, which will give the height of the gun deck at the midship frame. From the point Z set off 2 feet 7 inches 6 lines (the $\frac{1}{8}$ of the height of the gun deck at the midship frame,) through which point draw a line VT, parallel to CD, which will be the load-water line. Through the point F draw the line G*g*, parallel and equal to the load-water line, which will shew how much water the ship will draw abaft more than afore.

One of the frames is placed pretty near the cheffs tree, which is called the loof frame; to find its place, from the point of D set off $\frac{1}{4}$ of the line DC, and there draw a dotted line perpendicular to AB. Again divide the line FG into nine equal parts, and draw eight lines perpendicular to AB, which will station eight frames in the fore-body besides that of the loof.

There is in the after-body a frame to balance that of the loof in the fore-body; these two are of equal breadth in some points, and this will occasion the center of gravity of that part contained betwixt these two frames to be near the plane of the midship frame, which will keep the fore part and after part upon a balance. It must be as far abaft the middle of the line CD as that of the loof is before it.

The frames in the after-body are the same distance from one another as they are in the fore, which will occasion one more abaft than before; so there are nine abaft, besides that of the balance.

We shall in the next place lay down the deck lines, and first for the lower deck draw a fair curve through the points L Z *e*, and parallel to it draw another curve for the port-bells, which are 2 feet 5 inches above the deck line.

The

The aftermost port is 9 feet 3 inches before the post, which set off to *u*, and the ports are 2 feet 10 inches fore and aft; which set off from *u* to *x*, the distance betwixt the ports is 7 feet 9 inches, which set off from *x* to *Y* for the aft side of the second port; from *Y* again set off 2 feet 10 inches, which will give the fore side of the next. Proceed in the same manner till all the ports are spaced; so shall the foremost port be 17 feet 2 inches abaft the rabbit of the stem. The height of the ports is 2 feet 7 inches; which set up from *u*, draw a curve parallel to the deck line, which will give the upper part of all the ports; after which these two lines may be wiped off the draught, which must be therefore drawn with a black lead pencil, and only the ports inked in.

Draw a line for the upper deck, which is 6 feet 11 inches above the lower from the midship frame forward, and 6 inches more abaft. We may then draw a line for the port-fells, and one for their height parallel to the deck line, and space the ports so that they may be exactly over the middle of the distance betwixt the lower deck ports.

Before we can set off the height of the Quarter deck we must find the true place of the main mast. The general rule is to take 4 lines for every foot the gun deck is in length, and set it off abaft the middle, which will give the fore side of the mast: now the length 156 feet 3 inches $\times 4$ lines = 625 = 4 feet 2 inches 1 line, which set off abaft the middle of the line *CD*, and there erect a line perpendicular to the water-line, which will be the fore side of the mast, and parallel to it draw a line for the middle, and one for the aft side of the mast, the diameter of which is 35 inches. Set off 6 feet 6 inches on the aft side of the main mast, for the height of the quarter deck afore, and 6 feet 10 inches for the height abaft; and draw a line nearly parallel to that of the upper deck, which will be the line for the quarter deck. We may then space the ports, so that they may be exactly over those of the lower deck. The forecastle is 6 feet 6 inches high, at which distance draw a line parallel to the upper deck line, which will give the line for the forecastle deck. As to the length of this deck, it ends forward at the beak head, and is carried aft discretionally, observing to leave room for the capstan bars. In spacing the ports upon the forecastle, care must be taken that none be opposite to the fore mast. Now to find the center of this mast, take 15 feet 7 inches 2 lines, the tenth part of the whole length, which set off from the rabbit of the stem upon the lower deck abaft, from which point set off 32 inches and 1 line, being the diameter of the mast, through the middle of this draw a perpendicular line, as in the plate. The bolt-sprit generally makes an angle of 34 or 35 degrees with the load-water line.

The poop is pretty near parallel to the quarter deck; the distance betwixt them forward is 6 feet, an abaft 6 feet 3 inches. It ends about 18 inches before the mizen mast, the aft side of which is $\frac{2}{3}$ of the main breadth before the rabbit of the post upon the gun deck.

The counter is generally an arch passing from the upper side of the wing-transom to the lower side of the beam of the second deck. The rake of the lower counter is $\frac{2}{3}$ of an inch for every foot of the main breadth. The rake of the second counter is $\frac{2}{3}$ of the lower; its height above the deck is 3 feet 5 inches. The hollow of the counters is altogether arbitrary, insomuch that some give none to the lower. The upright of the stern rakes 2 inches in a foot, as in the plate.

The beauty of a ship depends much upon giving the wales a proper hanging; for by them the sheer and drift rails are regulated, being all nearly parallel to one another, though they generally rise a little more abaft on account of the accommodations for the officers. It is this which makes a ship look airy and graceful in the water. There is no certain rule for laying them down; this is left entirely to the fancy and taste of the artist; but in placing the wales great care must be taken that they be wounded as little as possible by the ports; the foremost port on the gun deck must be $1\frac{1}{2}$ or 2 inches above, and the third port from abaft just touch the upper side of the upper strake of the main wales. The lower edge of the lower strake may glance with the edge of the water when loaded. There are two strakes of wales, and one strake between them of 15 inches broad each. The range of the deck should be considered in placing the wales, so that the scuppers may be in the strake betwixt the wales. The like caution must be used for the channel wales as may be seen in the plate, where they are all laid down, together with the sheer and drift rails; the rails, cheeks, and knee of the head are likewise laid down in the plate, and being for an ornament to the ship, are left to the fancy and taste of the builder. Though the knee may help a ship to hold a good wind, the fore part of it is generally one twelfth part of the length before the stem.

C H A P. IV.

To lay down the Frames upon the Plane of Projection.

HAVING thus explained all that is necessary to be delineated upon the plane of elevation, the next thing to be determined is the different breadths of the ship at any assigned points of the length, whereby we shall gain the forms of all the planes that are made by sections, perpendicular to the load-water line. The timbers that compose the body of a ship are supposed to have their planes in that position, and may be all delineated upon the plane of the projection; but as both sides of a ship are exactly the same, it will suffice to lay down the half of each, those of the fore-body on the right, and those of the after-body on the left hand. And whereas these planes diminish afore and aft, the planes of all the frames may be all delineated upon the plane of the midship one, which may be called the master frame. The first thing then necessary to be known is how to form this frame.

The mid-ship frame is that which is at the broadest part of the ship. The builders differ about the form of this frame, but there are several preliminary operations which are necessary to be observed in all the different methods used in forming it.

Preliminary Operations for forming the Midship Frame,

Plate III, Fig. I. and II.] 1st. Draw the line A B to represent the upper side of the keel; it must be at least as long as the ship is broad. This line our author calls the line of *aculement*, because upon it the aculement of the midship floor timber terminates.

2^{dly}, Draw the line C D parallel and equal to A B, so that A C and B D may be equal to the rising of the midship floor timber. This line may be called the rising line, because it limits the height of the ends of the midship floor timber above the keel.

3^{dly}, Draw the line G H for the height of the lower deck parallel to the former, and below this draw a line to represent the load-water line, taking its distance below the deck line from the plane of elevation at the midship frame. Draw also the lines I K and L M, the one for the second deck, and the other for the sheer rail or top of the side in midships. The height of both are to be taken from the plane of elevation.

4^{thly},

4thly, Draw the line NO perpendicular to AB ; this is called the middle line, and represents the middle line of the stem and post, dividing the whole ship into two equal parts; and parallel to NO draw the lines AL and BM , to limit the breadth; also a line for half the thickness of the stem, and one for half the thickness of the post. Draw the lines xx parallel to NO , dividing the lines OA and OB into two equal parts. Draw also the diagonal GB . These lines being drawn, we may proceed to form the midship frame by some of the following methods.

M E T H O D I.

To form a Midship Frame that shall be neither too sharp nor too flat.

Plate III. Fig. I.] 1st, Divide the line ax , which marks the head of the floor timber into three equal parts; set off one from a to b .

2d, Divide the line dB , the distance betwixt the load-water line and the upper side of the keel, into seven equal parts; set off one of these from d to e , and from e to m , and draw the diagonal aV , which divide into two equal parts in the point n . *Note, the diagonal aV is wiped out after finding the point n .*

3d. Describe an arch of a circle to pass through the points b and e , make the radius the whole length and half the length of the line Be , so the center A may be found by describing an arch with that radius from e , and one from b to intersect one another in A , we shall only make use of that part of this arch betwixt b and m . Now, to find the other arches md , la , an , nV , it must be observed, that in order to reconcile two arches, so as to make a fair curve, a strait line must pass through the centers of both, and through the points where they unite or touch one another; draw therefore the lines Am and Al , so shall k be the center of the arch md , and o the center of the arch la . Again through the center o draw the line ao , produce it to P , which will be the center of the arch an . Lastly, from P thro' n draw the line Ps , s will be the center of the inverted arch nV . *Note, the center s will be without the Plate.*

4th. To form the top timber set back the tenth part of the half breadth from K to S , upon the line of the second deck; describe an arch of a circle thro' the points d and K , taking $\frac{2}{3}$ of the whole breadth for the radius: Again, from the point M , upon the line LM , set back the fifth part of the whole breadth to g . Describe an arch of a circle through the points S and I , taking the diagonal GB for the radius. As this arch is inverted in respect of the arch dS , the center will be without the figure. This compleats the form of half the midship frame, and by the same operations we may find the other half.

It must be observed that there is no regard had to the round of the beam in setting off the deck line or depth of the hold. M E-

M E T H O D II.

To describe a Midship Frame of a circular Floor.

Plate III. Fig. II.] From the center G , the point where the middle line intersects the deck line, making the half breadth the radius describe the arch b, G, c, O : Let d be the head of the floor timber, and dx the rising. Assume the point f , according to what round you propose to give to the second futtock, and describe the arch df ; the center may be found as directed in the preceding method. Divide the arch cO into three equal parts; set off one from c to g , and from the center b ; describe the arch dg : there remains only the inverted arch gY to be described; the center may be found as before directed.

M E T H O D III.

To draw a Midship Frame which shall be very full.

Plate III. Fig. III.] 1st. Draw the rising and deck lines as before; let dx be the rising.

2d. Make db the side of the square $dbac$ equal to Cb the $\frac{1}{4}$ of the breadth.

3d. Inscribe the two quadrants ceb , and cfb into the square.

4th. Divide the side ca into a certain number of equal parts in the points O, N, M, L, a ; draw the lines $iL, bM, \&c.$ perpendicular to ac .

5. Divide the line CG , the depth of the hold after deducting the rising, into the same number of equal parts in the points E, F, I, K , and make the lines Ep, Fq, Ir, Ks , in the frame, equal to the lines Ot, Nn, Me, Lm in the square, describe a curve through the points G, p, q, r, s, b , and the remaining part of the frame may be described by the preceding methods.

M E T H O D IV.

To describe a Midship Frame for a very sharp Ship.

Plate III. Fig. IV.] Let the length of the floor timber be half the breadth as before, and the rising one fifth or one sixth of the whole length of the floor timber; lay this off from x to E , and describe a parabola through the points G, P, Q, E , of which the point G is the vertex, and GC the axis. This method is extracted from M. Bouguer. The parabola may be formed by the following method: 1. Through the point E draw the line Tx perpendicular to GC , and the line dE perpendicular to AG , and produce

produce the line CG to D . 2dly, Upon the line GD find the center of a semicircle that shall pass through the points T , d , and D , so shall GD be the parameter of the parabola, by which we may find any number of points through which the curve must pass: for instance, suppose it were required to find a point in the perpendicular XP , through which the curve must pass; upon the line GD find the center of a semicircle which shall pass through the points D and X ; this will intersect the line AG in b , make bP equal and parallel to GX , so shall P be the point required; in like manner the points a Q f may be found. The remainder of the curve from E to y will be composed of two arches, the one to reconcile with the parabola in the point E , and the other inverted to pass through the point y ; the center of which may be found by any of the preceding methods. In order to find the center of that which joins with the parabola make TR equal to half the parameter GD , and draw the line ER , upon which find a point S for the center of the arch.

We might shew a great many more methods of describing this midship frame. It is very true that great care ought to be had in forming this frame, because upon it chiefly depends the form of all the other timbers; I say chiefly, but not altogether; for two ships may be similar as to their midship frames, and yet very different afore and abaft; and though the artists should make themselves acquainted with all the different ways of forming this frame, I should recommend that method to them which is the simplest and which gives them the most liberty to vary the form of it, according to every one's particular taste or fancy; and it is very possible there may be several other methods as easy and plain as those we have described. This frame being once formed, we may form all the rest upon the same plane. We shall in the next place shew the different methods used by the builders for that purpose.

The ancient builders not being acquainted with the methods of laying down their designs in a draught, found out a mechanic way of doing this only by help of the midship frame, which they might have formed by some of the preceding methods or any other contrivance of their own; and though this method is defective in several points, yet as it is an ingenious contrivance, we shall give it a place here.

METHOD I.

Of forming the Timbers by a Mould made to the Midship Frame; a rising Staff and overcast Staff.

Plate III. Fig. VII.] 1st. Having formed the midship frame and set off its scantlings, make a mould to fit both outside and inside, which may be called the bend mould

2d.

2d. Draw the line Zx to limit the head of the floor timber at d ; let du be the rising, and draw the line au ; let t be the height of the rising line abaft, and draw the line dt to represent the floor heads, or floor ribband. Set off dx from d to H ; and from e , the head of the first futtock, to 6 , and divide each into six equal parts, being the number of frames from midships to the balance frame.

3d. Divide the line au into five equal parts, and set off two of them from a to S ; divide the line aS into the same proportion, that the part $A6$ of the base AC of the right angled triangle (*fig. 5.*) is divided into, and transfer these divisions to the bend mould, and let them be numbered $0, 1, 2, 3, 4, 5, 6$, which points will give the narrowing of the floor, as we shall shew, after constructing the triangle. We shall only remark, that the line aS , which is $\frac{2}{5}$ of au , is nearly the difference betwixt half the length of the midship floor timber, and half the length of the floor timber at the balance frame. But as this appears to be too much, we may take $\frac{2}{5}$ as in the figure, or any other quantity which shall be thought most convenient.

To construct the Triangle, Fig. 5.

Upon the line AC , drawn at pleasure, set off any distance from A to 1 , and double that distance from 1 to 2 , treble from 2 to 3 , and so on in the same progression till we have as many divisions on the line AC as we propose to have frames abaft the midship. Erect a perpendicular at A , which may be produced at pleasure, and from any point B draw lines to all the divisions of the base AC . Observe that though in the triangle we have drawn a line for every frame to the fashion piece, we shall only make use of six, there being so many to the balance frame. The triangle being thus constructed, apply the line aS to it, in such a manner, that it may be parallel to AC , and be contained betwixt the lines BA and $B6$, the lines drawn from the point B to the points $1, 2, \&c.$ will divide it into the required proportion.

To construct the Rising Staff, Fig. 5.

This staff K may be of the same breadth with the keel, and a little longer than at , the height of the rising of the floor. In order to graduate that staff, set off xu , the rising of the midship floor from K to o , and make oL equal to at ; apply the line oL to the triangle, so that it may be parallel to the base, and contained betwixt the lines AB and BC the

E

lines

lines from the point B to the several points in the base will divide it into the required proportion, which will give the rising of the floor.

Note, Our author calls x u the acculement, and u d the rising ; the line u a will pass through the point where the inverted arch joins the floor sweep.

To construct the over cast Staff, Fig. 5.

That we may have a clear understanding of what is meant by *over-cast*, it will be proper to observe, that in forming the frames by the bend mould, when it is set to the narrowing of the floor, the head of the mould will come too far in at the deck ; the mould must therefore be moved round upon the point which represents the floor ribband, till the head goes out to the proper breadth ; this will occasion the lower part of the mould to rise a certain quantity, which is called the over-cast. In order to graduate this staff we must determine the difference betwixt the main breadth at the midship frame, and at the balance frame, which suppose D F, let this be placed parallel to the base, and contained betwixt the line B A and B 6 ; so shall the lines B 6, B 5, &c. divide it into the required proportion.

These are the instruments that are necessary for forming the after frames, those for the fore part are constructed in the same manner, only the graduations for these are but half the graduations of the former, for which reason there must be another bend mould graduated for the fore body.

Now, in order to form the frames by these instruments, place the bend mould upon the rising staff in such a manner that the middle line of the staff produced may pass through the narrowing of the floor upon the bend mould, expressed by the division corresponding to the frame to be formed ; suppose frame 6, (*Fig. 7.*) the lower or strait part of it expressed by the dotted line in the figure being applied to the rising staff, till the middle line B a pass through the division 6 on the bend mould : mark by the edge of the rising staff the point 6, which expresses the rising of the floor at that frame. Set up the over cast (expressed by the space contained betwixt the points 5 and 6 upon the over cast staff) from the lower part of the bend mould to the point 6 upon the line B a ; then keeping the point d immoveable, turn the bend mould upon this point till the lower part rise to the overcast at the point 6 upon the line B a, and when in this position we may describe the curve to the floor head, and then invert the bend mould, and placing the point 6 (betwixt d and H) to the point set off before to express the rising, turn the mould
till

till the strait part touch the curve before described, and then draw the lower part, which compleats the frame.

This is the method that is used when they mould the timbers, and it may likewise be used to lay them down upon a draught; for if the line *au* of the bend mould (*Fig. 8.*) be laid upon the line *AV*, we may, when in that position, describe the midship frame from the point *d* to the point *X*. In like manner we may describe all the rest of the frames, by giving each its proper over-cast and rising; as for instance, if it were required to describe frame 6, take the rising *K 6* upon the rising staff, and set it off from the point *B* to the point *a* upon the line *BG*, and draw a line through the point *a* parallel to *AV*, upon which laying the bend mould in such a manner that the point 6 which expresses the narrowing of the floor, shall be upon the point *a*; then will the point *d* be upon the point *RS*: set up the proper over-cast from *a* to 6, and keeping the point *d* immoveable, push up the bend-mould which at first was placed at the point *a*, till it be raised to the point 6, which will throw out the point *X* to the proper breadth at the deck. But because the deck is higher at timber 6 than at the midship frame. Take the distance betwixt *e* and 6, at the head of the futtock on the bend mould, and set it up from *x* to 6, and then inverting the bend mould, so that the point 6 betwixt *d* and *H* be at the point *X*, and the strait part of the mould touch the curve before described: we may then describe the lower part to the point *X*, which compleats the whole frame. The timbers for the fore body may be described by the same process as those of the after body, only making use of the bend mould, rising and overcast staff graduated for that purpose; but as we observed before, we cannot lay down any timbers by this method but those betwixt the midship and ballance frame.

The builders finding how very advantageous it would be for them to form all the timbers upon the plane of the projection, because they could then at one view see how they would compare one with another, have tried several expedients to perform this, of which I might instance ten or twelve, but shall content myself with explaining three, which may be sufficient for those purposes, in order to which I shall first shew another method of forming the midship frame, different from those we have shewn before.

Plate III. Fig. 6: 1st. Draw the rising deck and load-water lines, and set off the length of the floor timber as before.

2^d. Take one fourth of the length of the floor timber, and set it off from *O* to *d*, upon which erect the perpendicular *dc*, and divide it into two equal parts in the point *e*. 3^d.

3d. Describe an arch through the point a , the head of the floor timber, and the point e , taking for the radius the distance from the upper edge of the keel to the port-sells, or a little more or less, according to what round you propose to the floor head. This determines the rising of the floor timber, and with the radius $O I$, half the length of the floor timber, describe the arch $e Y$, which determines the *aculement* of the floor timber.

4th. At the point l , the middle of the line $A O$, erect the perpendicular $l m$; and at the point n , the middle of the line $A l$, erect the perpendicular $n o$; erect also the perpendicular $p q$ at the middle of the line $A n$; and another $r s$, at the middle of the line $A p$; and lastly, another $t u$, at the middle of the line $A r$.

5th. Take the distance $l n$, which set off on the line $n o$ from n to x ; and on the line $p q$, from p to g ; then taking the distance from a to g set that off from p to y ; again take the distance $p y$, which set off from r to b , and the distance $b a$ from r to F ; and lastly take the distance $r F$, which set off from t to E , and then the distance $E a$ from t to x , a curve passing through the point a, x, y, F, x, T , will form the midship frame under water. We may then set off half the thickness of the post and stem on each side of the middle line, and form the rest of the timbers; those for the fore body on the right, and for the after body to the left of the middle line.

Plate II. 1st. To lay down the post upon the plane of projection, take the difference of the draught of water abaft more than in midships, as marked on the plane of elevation (*Fig. 2.*) set off this from F to d (*Fig. 3.*) and draw the line $d e$ parallel to $A B$; take also $K F$, the height from the plane of elevation, which set off from e to r , so shall the point r be the head of the post.

2d, to lay down the wing transom, take its height from the plane of elevation, which set up on the plane of projection to f , and draw the line $g f$ perpendicular to the middle line, so $g f$ represents the upper side of the wing transom without regarding the round up or the round aft. Take also the height of the rising line upon the post from the plane of elevation, which set off from e to G .

3d. To form the fashion piece; take upon the plane of the projection $n G$ the height of the load-water line, above the rising line upon the post, which set off from n to o upon the water line; take also $G P$, the distance betwixt the rising line and lower deck, which set off from P to q upon the deck line, and describe a circle through the points f, q, o . There is a problem in geometry to find the center of this arch. *Note*, the point q may be taken further out or in, as you design a lank or full fashion piece.

Lastly,

Lastly, describe the arch $o G$; the radius of this arch may be the main half breadth; so shall f, g, o, G be the form of the fashion piece, which may be varied according to the fancy of the artist, by altering the centers.

Having thus formed the midship and after frames, we shall in the next place shew how to space the ribband lines, which are represented by the diagonals in the figure, but it will be proper to remark, that the ribbands are thin narrow planks which are made so, that they may easily be bent to the timbers. That which is nailed to the post at the height of the rising line, and to the midship frame, at the end of the rising of the floor timber, is called the floor ribband. That which answers to the wing transom and to the height of the lower deck, on the midship frame, is called the breadth ribband; all the rest betwixt these two are called intermediates.

From the Point H draw the line $H G$ for the floor ribband, and from the point T draw the curve T, E, q, p for the breadth ribband, and draw the two intermediates betwixt them, so that by them the curve of the midship frame and fashion piece may be divided into three equal parts.

Now, it is very plain, that if the ribbands had a proper form, and nail'd at the proper heights and positions, they would compose a kind of a model, by which the circular form of every timber might easily be discovered; but as we have only the extreme points of each given, we cannot from thence form such a curve as shall be necessary. We must therefore find a method to form some intermediate timbers betwixt the midship and after one, and thereby form the ribbands so that they shall make fair curves. There are some preliminary operations which are necessary towards performing this.

1st. To construct an equilateral Triangle for the Progression of the Frames in the After-Body.

Plate IV. Fig. 1. From the point M set off any distance to 1 , upon any strait line, and from 1 to 2 treble that distance, from 2 to 3 five times that distance, from 3 to 4 seven times that distance, and proceed in that progression, increasing the spaces betwixt the figures by equal differences, *viz.* double the distance betwixt M and 1 , till we have as many divisions less one as there are frames betwixt the midship and post, including that of the midship and post; and because there are nine frames the line must consist of ten divisions, from the point M to the point E . Let them be numbered $1, 2, 3, \&c.$ make $M E$ the base of an equilateral triangle $S M E$, and draw the lines $S 1, S 2, \&c.$ observing to produce them all till the distance betwixt the lines $S E$ and $S 9$, upon a line parallel to the base, be at least equal to the distance betwixt the frames in the plane of

of elevation. The line *S M* represents the midship frame, and the line *S E*, the post, and the nine intermediates, represent the nine frames betwixt the midship and post.

In order to give us a clear understanding of the use of this triangle, it will be necessary to remark, that the midship frame being that which incloseth the greatest space, and the aftermost that which incloseth the least, it will follow, that the intermediate frames will partake of the form of each; but mostly of that to which they are nearest; yet they will still retain a little of the form of each. Hence, when the intermediate frames are all formed, their curves will divide all the diagonals, drawn in the plane of projection, into as many parts as there are frames; and all the methods the builders have invented serve only to divide them into such a proportion as shall produce the fairest curves.

Now, if the proportion pitched upon for that purpose, be as 1, 3, 5, 7, 9, &c. then they must all be divided into the same proportions as the base of the triangle is divided into; and this may be performed very readily, only by taking the length of each diagonal from the plane of the projection, and applying it to the triangle in such a manner that it shall become the base of an equilateral triangle; as for instance, to divide the first intermediate diagonal; take the length of it in the plane of projection, (*Plate II. Fig. 3*) and set it off from the point *S* to *m* and *k* on the sides of the triangle *S M* and *S E*; and draw the line *m k*, which being parallel to the base of the triangle, will be divided into the same proportion. In like manner all the rest of the diagonals may be divided; but as the builders are not agreed as to the precise form of a ship's bottom, some chuse to divide the base of the triangle into another proportion; others again in applying the diagonals to the triangle give them different inclinations to the line *M S*. It would be very proper to try several of these methods, by which means we might discover which would be most convenient; and after all the diagonals are divided into as many points as there are frames, curves passing through these points will determine the form of all the frames from the midship to the post. It only remains to shew how to end each frame upon the post. It was before observed that the keel is not parallel to the surface of the water, so that it will be very easy to conceive that the height of each frame taken from the upper side of the keel, upon a perpendicular to the surface of the water, will always increase, the nearer the frame is to the stern post. Now *g K* is what the keel is deeper abaft than at the midship frame; and to find how much any frame abaft exceeds that of the midship, suppose the first; take the distance betwixt the line *g G* and *K I* at that frame, from the plane
of

of elevation, (*Plate II.*) which set off from F towards *d*, (*Fig. 3.*) and at that point draw a line parallel to *d e*, which will be the first frame upon the keel. In like manner we may draw lines parallel to *d e*, for all the rest, as in the figure, which will determine their heights from the upper side of the keel to the surface of the water.

It must be observed, that the diagonals in the plane of the projection, which end on the fashion piece, must likewise end on the fashion piece on the plane of elevation; we must therefore draw the fashion piece on the plane of elevation. Thus, take the distance of the point G, in the plane of the projection, from the upper side of the keel, which set off upon the stern post in the plane of elevation to the point *b*; through *n*, the rabbit of the wing transom, draw the strait line *b n*, which will represent the fashion piece on the plane of elevation. Now as only the lowest diagonal ends upon the post, in the plane of projection, which in the plane of elevation ends at *b*, so the other diagonals that end upon the fashion piece, must likewise end on the fashion piece in the plane of elevation. Their height must therefore be transferred from the plane of the projection to that of the elevation; so the second diagonal will end at the point P, upon the fashion piece in the plane of elevation. In like manner all the rest may be transferred to the plane of elevation; and as the line that represents the fashion piece upon the plane of elevation rakes aft, this will occasion the line P S, which is perpendicular to the line that represents frame 9, to exceed the line *b M*. In the triangle, the line S M represents the midship frame and the line S E the post; that is, if the point where the ribband ends on the post, be equally distant from frame 9, that frame 9 is from frame 8. Now as *M b* is longer than *M L*, we must draw the line S D without the triangle, which is to be used instead of the line S E, when we come to apply the diagonal H G to the triangle; for the point H must touch the line S M, and the point G the line S E. To find the point D, take *M L* from the plane of elevation, and apply it to the triangle, so that B C shall be equal to it; and parallel to M E; it must also be contained betwixt the line S 9 and S E. Then take *b M* and set off from B, which will give the point D. In like manner the line S F must be used when we divide the diagonal M K; and to find the point F set off P S in the plane of elevation, from B to F in the triangle; and draw the line S F. In the same manner there must be lines drawn for every diagonal without the line S E; so the line S E is not used in dividing the diagonals. Let it be further observed, that in applying each diagonal to the triangle, it must not only be contained betwixt the line S M and the line corresponding to the diagonal, which is to be divided, but it must likewise form a certain angle with the line M S, that

that is, with that part of it which is intercepted betwixt the diagonal and the point S. These which appear to me to be properest for that purpose are as follows: The first diagonal to make an angle of 60 degrees; the second $62\frac{1}{2}$, the third 68, the fourth 86, the fifth 65, the sixth 60 degrees; but the artists vary these angles according to the form they design to give to the timbers; nay, some draw them always parallel to the base of the triangle.

Our author then proceeds to the forebody, and forms a triangle, the base of which he divides in the same manner as that already described, by which he divides each diagonal. He likewise shews how to space the diagonals upon the stem; but as the artists leave us so much undetermined as to the angles that each diagonal is to make with the line SM, when they are applied to the triangle, it will be very difficult to apply this method to practice. So we presume it will be needless to say any more on that head, judging what has been already said sufficient to give our readers an idea of the principles on which the method is grounded; we shall proceed therefore to the next method he proposes.

To form the Timbers by a Quarter of a Circle, Plate IV. Fig. 2. 3.

1st. Form the midship frame, the fashion piece, the foremost timber, also the two balance frames, by some of the preceding methods. Note, Those who make use of the following method of forming the rest of the timbers are supposed to be previously acquainted with the manner of forming the midship frame, &c.

2d. Space all the diagonals for the ribbands as directed in the preceding method.

3d. From the center A with any radius describe a quarter of a circle, and divide it into so many equal parts, that there may be a point for each timber to be formed, and draw the radii A 1, A 2, &c. to A 9, so we shall have one for each frame.

4th. Take *ab* the first diagonal, which set off from the point A upon the line AC, to 1.

5th. Take *ac*, the distance upon the lower ribband, betwixt the post and balance frame, which in the plane of projection is the 6th frame, set off this distance upon a perpendicular erected upon the line AB, to intersect the radius A 6, in such a manner that the perpendicular G 1 shall be equal to *ac*.

6th. Produce the line CA to F, and upon this line find a point, which shall be the center of a circle whose circumference shall pass through the point 1, before marked upon the line AC, and the point 1, now marked upon the radius A 6; describe the arch through these two points to the point 1 on the line AB.

7th,

7th. Let fall perpendiculars to the line A B from the points where the arch 1, 1, 1 intersects the several radii. Transfer these perpendiculars to the line *a b*, which will divide the lower diagonal into the points through which the curves of the frames must pass. *Note, the perpendiculars are not drawn to avoid confusion.*

After the same manner all the other diagonals are graduated, first by taking the whole length of each diagonal, and setting them up on the line A C, from the point A to the points 5, 4, 3, 1, 2, and secondly, by taking the several distances upon each diagonal intercepted betwixt the after frame and the balance frame, and applying them severally to the radius A 6, in such a manner that they shall be contained betwixt the radius A 6 and the line A B, upon the perpendiculars let fall from the points 5, 4, 3, 1, 2. And thirdly by describing arches through the points in the line A C, to pass through the points of the same number upon the radius A 6, whose centers are in the line A F; the arches to be produced to intersect the line A B in the points 5, 4, 3, 1, 2, will intersect all the radii; the perpendiculars let fall from the intersections of the radii with the arch corresponding to each diagonal, will divide that diagonal into the points through which the curves of the frames must pass.

The diagonals for forming the frames in the fore body are divided into the points through which the curves must pass by the same operations, only observing that frame 4 is the balance frame for the fore body.

C H A P. V.

Of the Projections on the horizontal Planes, and of the Water and Ribband Lines on the Plane of Elevation, and that of the Projection.

WATER Lines are described upon a ship's bottom by the surface of the water into which she swims; that which determines how much is under water when she is loaded is called the load-water line. Now it is plain, that if a ship is lightened, she will rise higher out of the water; and if she be lightened so as to rise equally afore and abaft, the surface of the water will then form another water-line parallel to the load-water line. Again, if the ship is lightened more she will still rise higher, and if the same difference still continues betwixt the draught of water abaft and afore, we shall have another water line parallel to the two former;

F

so

so that by this means we may describe as many water lines as we please, all parallel to one another.

In order to form an idea how these lines are represented on the different planes, let us suppose a ship upon the stocks upon a level ground, and her keel in the same position, with respect to the horizon, that it is to be in the water when loaded; we may then describe several black lines upon the ship's bottom, which may be whitened for that purpose, all parallel to the horizon: These will all be water lines.

Now, if a spectator be removed at any considerable distance from the ship upon a line in the same direction with the keel, all these black lines which were drawn upon the ship's bottom, parallel to the horizon, and which are actually curves, will appear to him all strait lines, because he sees them all upon a plane formed by a section passing through the mid-ship frame perpendicular to the keel. Hence the water lines will be represented by strait lines upon the plane of the projection.

Again, if a spectator is removed at any considerable distance from the ship upon a line perpendicular to the keel, so as to see the whole length of the ship at one view, the water lines will then appear to him strait lines, because he sees them upon a plane erected perpendicular to the horizon upon the middle line of the keel. Hence the water lines will be represented by strait lines upon the plane of elevation.

But if the spectator be supposed to be placed underneath the middle of the ship at any considerable depth, in a line perpendicular to the level ground, he will then, viewing the ship's bottom upwards, discover the curvings of all the water lines. These curves are all projected upon a plane, which we must imagine to be formed by a section of the ship through the load-water line, and we are now to shew how these are formed:

To form the Water Lines upon the Horizontal Plane.

Let the water lines to be formed be represented in the plane of the projection by strait lines all parallel to one another. These will be represented by the strait lines in the plane of elevation. Suppose qr , st , bx , and TV , all parallel to one another, and the same distance from the load-water line TV that the lines which represent them in the plane of the projection are from it. In order to form these upon the horizontal plane,

1st, Take half the thickness of the post from the plane of the projection, and lay it off on the horizontal plane from A to E , and through the point

point E draw the line Es parallel to A B, five or six feet long; lay off the same distance from B to F, and thro' the point F draw a line F R parallel to A B, five or six feet long.

2d. From the points where the water lines intersect the stern post upon the plane of elevation, let fall perpendiculars. In like manner let fall perpendiculars from the points where the water lines intersect the stem.

3d. Take upon the water lines, in the plane of the projection, the several distances intercepted betwixt the middle line and the curve of the midship frame, and lay them off from the line A B in the horizontal plane, upon the perpendicular that represents the midship frame. Take also from the plane of projection the several distances intercepted betwixt the middle line and the curvings of the other frames, and lay them off in the horizontal plane from the line A B upon the perpendiculars corresponding to their respective frames, both in the fore body and after body, and curves passing through all these points will give the true form of all the water lines. They end forward at the points where the perpendiculars intersect the line F R. The water lines abaft which end upon the post in the plane of elevation, will end where the perpendiculars intersect the line Es upon the horizontal plane. But the 3d and 4th water lines cannot end upon the post, by reason of the fashion pieces; and in order to find the points where these shall end, we must proceed in the following manner.

To find the point where the load-water line ends, let fall a perpendicular from the point *k*, where it intersects the fashion piece on the plane of elevation, to N. Take from the plane of the projection upon the line that represents the load-water lines, the distance betwixt the fashion piece and the mid-line; lay this off upon the horizontal plane from the line A B to the point N, which will end the load-water line upon the horizontal plane, from whence it may be drawn to *g*; so *g* N will be the flat of the Tuck; and to find the point *g* draw a line parallel to *k* N thro' the point where the line T V cuts the rabbet of the post, which will give the point *g*. We may after the same manner find the ends of the other water lines that do not go the stern post for a square tuck.

To form the Ribbands upon the Horizontal Plane.

We observed before, that the ribbands were thin planks nailed to all the frames from the post to the stem; and that when they are carried round, so as to make fair curves, the form of all the filling timbers may be by them determined. These filling timbers are to be placed betwixt

the frames, which were methodically laid down in the draught. We shall here further observe, that these ribbands will round two ways, one in a vertical, and one in an horizontal sense, occasioned by the nature of the form of the ship's body; for they will, in carrying them about, naturally fly higher abaft and before than they are in midships, which gives them a vertical curve, and the narrowing of the ship's breadth from the midships both ways gives them the horizontal curve; thence they will be represented by different lines on all the planes.

They are represented upon the plane of the projection by straight lines, all but the breadth ribband, which is usually represented by a curve; but upon the plane of elevation, and that of the horizon they will be represented by curves. The reason of these different appearances, arises from the different situations in which they are supposed to be viewed, as was observed in respect of the water lines.

Now in order to comprehend the relation betwixt these horizontal curves, and the lines that represent them upon the plane of the projection, it will be sufficient to remark, that these horizontal curves result from the different lengths of the perpendiculars that are supposed to be drawn in the plane of the projection, from the points where the lines that represent the ribbands intersect the frames, to the middle line. Hence, if the lengths of these perpendiculars are transferred to the lines corresponding to each frame in the horizontal plane, we shall have the points thro' which the curve that forms the ribband must pass.

But if these ribbands are to be represented upon a plane placed in an oblique position to the horizon, that is to say, a plane that has the same inclination to another plane erected perpendicularly upon the middle line of the keel, that the line that represents that ribband, has to the middle line in the plane of the projection; in that case, they will have a quite different form from what they have upon the plane of the horizon.

Now, to conceive the relation betwixt these and the lines that represent them upon the plane of the projection, it will be sufficient to remark, that if the several distances taken upon each diagonal intercepted betwixt the middle line and the points where these diagonals intersect the curves of the timbers in the plane of the projection; I say, if these be transferred to the lines that represent those timbers, we shall have the points thro' which the curves that form the ribbands must pass.

Again, if these ribbands are to be represented upon the plane of elevation, they will have a different form from any of the former; to find which we need only take the perpendicular distances from the points where the diagonals intersect the curves of the timbers in the plane of
of

of the projection to the line that represents the upper side of the keel, and transfer them to the plane of elevation, setting them up from the upper side of the keel upon the line corresponding to the timber, from which they were taken upon the plane of the projection. This will give us the points thro' which their curves must pass.

Having thus given a general description of these curves, we shall now proceed to describe them upon the different planes.

To describe the Floor Ribband upon the Plane of Elevation.

1st. Take the perpendicular distance betwixt the point *a*, where the diagonal intersects frame 9, and the lower water line in the plane of the projection.

2d. Set up this distance from the point *S*, where the lower water line intersects frame 9 in the plane of elevation, and we shall have a point *G*, thro' which the curve must pass.

Now, it is plain, that we may, by repeating the same operations, have a point in each frame, thro' which the curve of the ribband must pass upon the plane of elevation. After the same manner are all the other ribbands formed.

To describe Ribbands upon the Horizontal Plane.

The breadth ribband is formed by transferring the lengths of all the perpendiculars that are supposed to be drawn from the points where the curve that represents this ribband intersects the timbers, to the middle line in the plane of the projection: This curve, in the plane of the projection, is drawn from the breadth in midships to the extremity of the wing transom.

1st. Lay off the length of the wing transom upon the perpendicular *n L*.

2d. Take the length of the perpendicular drawn, from the point where the curve that represents the breadth intersects frame 9, to the mid-line in the plane of the projection; lay off this from the line *AB* upon the perpendicular representing frame 9 in the horizontal plane, to the point *S*, which will be one of the points thro' which the curve of the ribband must pass. We may proceed in the same manner to find points upon all the perpendiculars, both afore and abaft, so shall the curve *L, S, Q, r*, be the form of the breadth ribband. But to compleat this ribband, the round aft of the wing transom must be set off.

To form the Oblique or Cant Ribbands.

We observed before, that these ribbands could not be formed either upon the horizontal plane or that of elevation, upon which account they were seldom drawn, because each must be drawn upon a separate plane. However, those who incline to draw them may use the following method:

Let it then be required to form the first ribband represented in the plane of the projection, by the diagonal *H G*.

1st. Produce line *H G* to the point *p* in the middle line upon the plane of the projection.

2d. Take the height of the point *p* above the line that represents the upper side of the keel in midships, in the plane of the projection; set up this from the same line in the plane of elevation, on a perpendicular, upon the post, from which point let fall a perpendicular to the point *F* in the line *CD*, and produce all the perpendiculars that represent the frames to the line *CD*; so *F, Q* will be the axis of the ribband from the post to the midships.

3d. Take upon the plane of the projection in the line *H P*, the distance *p G*, which set off upon the perpendicular from the point *F* to *f*,

4th. Take the distance on the diagonal from the point *p* in the middle line to its intersection with the frame 9. Set off this from the line *CD* upon the perpendicular corresponding to frame 9; this will give us a point thro' which the curve must pass. Do the same for all the other frames to the midship.

In like manner the curve for the fore part of the ribband is formed from the intersections of the diagonal 4, 5, with the curves of the frames in the plane of the projection; but it is evident, this is a different plane from that of the line *H p*; therefore we must have a different axis for the curve of the fore part of the ribband. In order to which, take from the plane of the projection the diagonal 4, 5; set off this from the point *O* to *Z*, and draw the line *Z X* parallel to *CD*. We must likewise take the height of the point 4 in the plane of the projection, and set it up on the stem; from which point letting fall a perpendicular to the line *Z X*, we shall limit the fore end of the ribband. The points thro' which the curve must pass will be found in the same manner as those for the after-body.

The builders make use of the cant ribbands to find the bevellings of the timbers; For we must represent each frame as one intire piece of circular timber, and being all fastened to the keel they form the side of the ship. They are square upon the upper side of the keel; but because
both

both the outside and inside of the ship's sides, length-ways, form curves, it is plain, that the sections of any of the frames, the midship only excepted, will produce a surface in the form of a lozenge or rhombus; the angles which are formed by these sections are what are called the bevellings of the timbers.

The ship-wrights take these angles mechanically by an instrument call'd a bevel; thus they draw, upon the plane of the ribband, a line parallel to that which represents the frame, and distant from it the whole breadth of the timber; and applying the stock of the bevel to the line that represents the frame, and the tongue to the ribband, they have the quantity of the angle which forms the bevelling of the timber at that place.

It is plain the angle b, a, c , which points to the midship frame, will be obtuse, whereas the angle b, a, d , which points to the post, will be acute.

Now, as every timber has two planes, that which points to the midships will have what they call a standing bevelling, and that which points either to the post or stem will be under bevelling.

We shall shew in another place how the modern builders, by putting the frames in an oblique position to the keel afore and abaft, lessen the bevellings.

C H A P. VI.

Another Method of laying down the Horizontal Plane, and the Plane of Projection.

THOSE who are well versed in the art of drawing have taken a method quite different from any of those we have described, which shall be the subject of this chapter.

After forming the plane of elevation, and drawing all the perpendiculars for the frames, as before, the following method must be observed:

I.

To lay down the Breadth Ribband on the Horizontal Plane.

The extremities of it on the stem and post, and the point thro' which it is to pass on the midship frame are found as directed in the preceeding chapter. It remains now to find the points in the balance frames, thro' which it is to pass.

To find the point in the fore balance frame take $\frac{1}{2} \frac{8}{10}$ parts of half the
main

main breadth, which set off on the line that represents that frame in the horizontal plane from K to L.

To find the point in the balance frame abaft, take $\frac{1}{16}$ parts of the half of the main breadth from M to N. It will be necessary to have another point in the fore-body, thro' which the curve must pass; for which purpose use the following method:

Divide the space contained betwixt the line that represents the balance frame afore and the rabbit of the stem, into two equal parts, and draw the line OP, on which set off the 160th part of the main breadth, which will give the point P, thro' which the curve is to pass. It must be observed, that the proportions for finding these points may be varied according to the form we propose to give to the ribband. After the points H, N, Q, L, P, I are thus set off, we may describe the curve either by moulds or penning battens.

II.

To lay down the Floor Ribband on the Horizontal Plane.

1st. The height of this ribband must be determined both upon the post and stem, from which points letting fall perpendiculars, we shall have the extremities of it on the horizontal plane, observing to allow for the rabbit.

2d. Take half the length of the midship floor timber, and set off on the line that represents the midship frame on the horizontal plane from *a* to S, which will be the point thro' which the curve must pass.

3d. Take $\frac{1}{16}$ of the line *a s*, the breadth at the midship frame, and set it off on the balance timber afore, from K to T, and set off $\frac{1}{16}$ of the same line, upon the balance timber abaft to V, and draw the curve thro' the points G, V, S, T, R.

III.

To lay down the after Balance Timber upon the Plane of Projection.

1st. Produce the line which represents it on the horizontal plane to the sheer rail, on the plane of elevation, and take the distance upon this line betwixt the upper side of the keel, and the lower edge of the second wale, which here represents the breadth ribband; set up this from A to C on the plane of the projection, from which point draw the line C D, perpendicular to the middle line. (*Plate II. Fig. 1, 2, 3.*)

2d. Take the line M N in the horizontal plane, and set off from D to E, which will give one point, through which the curve of the timber must pass.

3d. Take

3d, Take the height of the floor ribband, in the plane of elevation, and set it up on the plane of the projection to G; from the point H, at the end of the floor timber, draw the line H G which will represent the floor ribband on the plane of the projection. (*Plate II. fig. 1. 2. 3.*)

4th, Take the distance M V, in the horizontal plane, with a pair of compasses, and move the compasses with one foot, in the middle line, and the other in a line perpendicular to it, till it intersect the diagonal in the point L, thro' which the curve of the frame must pass. To those who are acquainted with drawing, the three points E, L, F, will be sufficient to form the timber; they who incline to have another point may divide the line A C into two equal parts by a perpendicular M K drawn to the middle line, from which setting off $\frac{1}{2} \frac{3}{8}$ of the line M K we shall have another point thro' which the curve must pass.

IV.

To lay down the ninth Frame abaft on the Plane of the Projection.

Take the height of the breadth ribband at this frame, in the plane of elevation, and set it up on the plane of the projection from F to O, and draw the line O P perpendicular to the middle line. (*Plate II. fig. 1. 2. 3.*)

2d, Take the distance X S in the horizontal plane, and set off from O to P, which will be the point thro' which the curve must pass.

3d, Take the distance X Z in the horizontal plane, which set off from the middle line, to intersect the diagonal that represents the floor ribband, in the plane of projection in Q, observing to keep the compasses as before directed.

4th, Divide the line K O in two equal parts, and draw the line R S perpendicular to the middle line, on which set off $\frac{1}{2} \frac{3}{8}$ of the line P O, from R to S, and draw the curve thro' the points P, S, Q, F, which will be the form of the ninth frame.

V.

To lay down the intermediate Ribbands abaft on the Plane of the Projection.

1st, Take the distance betwixt the upper side of the keel and the breadth, upon the line that represents the midship frame, in the plane of elevation, and set it up from A to T, and from B to T, in the plane of the projection, so shall the line T T give the height of the breadth ribband in midships.

2d, Divide the curve H M T into as many equal parts as there are to be intermediate ribbands; divide also the curve of the ninth frame Q S P into the same number, and, thro' these divisions, draw the diagonals which will represent the ribbands as in the plate.

VI.

To lay down the first intermediate Ribband upon the Horizontal Plane.

1st, Take the nearest distance of the point V (which is the extremity of the diagonal in the plane of the projection) to the middle line OF, set off this on the line which represents the midship frame in the horizontal plane, which will give the point thro' which the curve must pass at that place. After the same manner we may find the points in the lines that represent the balance and ninth frames in the horizontal plane.

2d, Take FZ, the height of the ribband upon the rabbit of the post, in the plane of the projection, and set it up on a perpendicular, from N to the point *k* on the line that represents the rabbit of the post in the plane of elevation; take the nearest distance of the point *k* to the perpendicular of the post, which set off from E to *e*, and this will be the end of the ribband: so a curve passing thro' the points *e, d, c, b*, will be the form of the ribband.

VII.

To lay down the Wing Transom upon the Plane of the Projection, and on the Horizontal Plane.

1st, Take the height of the upper side of the wing transom (including the round up) in the plane of elevation, and set it up in the plane of the projection to the point *e*.

2d, Take the height in the plane of elevation, without regarding the round up, and set off from F to *f*, and draw the line *fg* perpendicular to the middle line, on which set off the length of the transom from *f* to *g*, this is equal to the line GH in the horizontal plane. The curve *ge* represents the upper side of the wing transom.

The round aft of the transom is represented upon the horizontal plane by the curve L *ke*; HL is the square end of it.

VIII.

To lay down all the Frames in the after Body.

All these are laid down in the same manner as the ninth and balance frames before described, that is, by taking the half breadth of the ribbands at each frame in the horizontal plane, and setting them off from the middle line in the plane of the projection to intersect the diagonal corresponding to the ribband, as directed in forming the balance frame, by this means we shall divide each into as many points as there are frames: the curves drawn thro' these points will give the form of all the frames in the after body.

IX. To

IX.

To lay down the Position of the Fashion Piece on the Horizontal Plane.

Let fall the perpendicular GH, from the end of the wing transom, and draw the line H I, which will represent the plane of the fashion piece upon the horizontal plane, observing to make the angle G H I, about 25 degrees.

X.

To form the Fashion Piece in the same Manner it is to be, when put into its proper place in the Ship.

The fashion piece laid down in the plane of the projection, regards that frame as it would appear when viewed from abaft; but as the fashion pieces on each side are not in one plane, as all the rest of the frames are, we shall be much deceived, if we imagine that the fashion piece laid down in the plain of projection, will give the true form of that which is to be put in the ship. We must therefore lay it down upon another plane, and, to avoid confusion, we shall separate it from the plane of projection.

Note, The fashion piece, mention'd by our author, described in the plane of the projection, is that betwixt the ninth frame, and the curve f q o G, which represents the fashion piece of a square tuck; it is formed in the same manner as the rest of the frames, by transferring the lines n m, p o, &c. in the horizontal plane, to the plane of projection, to intersect the diagonals corresponding to these ribbands in the points i, l, &c:

1st, Draw the line f G, to represent the middle line of the plane of projection. (Fig. 4.)

2d, Draw the line f g perpendicular to G f, to represent the wing transom.

3d, From l, the point where the fashion piece intersects the floor ribband in the plane of the projection, take the nearest distance to the line f g, which represents the wing transom, and set off this distance in Fig. 4. from f to b, and draw the line b l parallel to f g.

4th, From the point l, where the fashion piece intersects the first intermediate diagonal, in the plane of projection take the nearest distance to the line f g, set it off from f to k, in Fig. 4. and draw the line k m, parallel to f g.

5th, In like manner, the points where the fashion piece intersects the second and third diagonals in the plane of projection, are to be transferr'd to the points q and n, Fig. 4. and the lines p q, n o drawn parallel to f g.

6th, To find the points through which the curve must pass: Take the line lH , which represents the position of the fashion piece upon the horizontal plane; lay this off from f to g : Again, take the distance ly in the horizontal plane, which lay off from q to p , in like manner set off the distance lz , from n to o ; and the distance lp from k to m , and lastly, the distance ln , from b to l ; so a curve drawn through the points g, p, o, m, l , will give the true form of the fashion piece.

XI.

To lay down the Fashion Piece upon the Plane of Elevation.

1st, Take the several heights above the keel, of the points where the fashion piece intersects the diagonals in the plane of projection, and transferr them to the lines o, p, q, z, y , in the plane of elevation, drawn parallel to the keel, and the same height above it, that their corresponding points are in the plane of projection.

2d, Take the nearest distance of the point n , in the plane of elevation, to the line CF , the perpendicular from the head of the post, set off this from the same line in the plane of elevation upon the line p ; which will be the point through which the curve must pass.

3d, In like manner the points z, y , must be transferr'd from the horizontal plane, to the plane of elevation in the points z, x , a curve passing through these points will be the projection of the fashion piece on the plane of elevation.

We shall hear remark, that some builders to avoid giving a great bevelling to the timbers, and likewise that they may not require such compass timber, do change the direction of all the frames in the fore-body before that of the loof; that is, the lines that represent them in the horizontal plane make an acute angle with the line that represents the keel; these are called cant timbers, and may be formed in the same manner as the fashion piece, which we have now described. Tho' several builders form all the frames perpendicular to the keel, to have the floor timbers in one piece, which will be much stronger than when in two pieces, and this will inevitably be the case when the timbers are canted.

We might here shew how to lay down the top timbers, but as that part under water is the most material, we shall proceed to form the timbers afore.

XII.

To lay down the Frames for the Fore-body.

The balance and the eighth frame must first be formed in the same manner as the balance and ninth frame abaft: In order to which the curve
that

that represents the breadth ribband must be laid down in the plane of the projection afore. The diagonal, which represents the floor ribband must likewise be laid down in the plane of the projection, for which purpose we must take the height of the ribband above the keel upon the rabbit of the stem, and set it upon the line that represents the rabbit of the post in the plane of the projection, to the point 4; from which draw a line to the floor head, so 4 5 will represent the floor ribband.

XII.

To space the Diagonals that represent the Ribbands afore, in the Plane of the Projection.

1st. As the points of their interfection at the midship frame are the same afore that they are abaft, we need only transfer them from abaft to the fore body.

2d. Take the height of the breadth ribband upon the stem in the plane of elevation, and set it up from F to 17 in the plane of projection.

3d. Divide the distance betwixt 4 and 17 into four equal parts, which will give the points in the plane of projection, where the intermediate diagonals end on the stem.

After the diagonals are drawn in the plane of the projection, the ribbands may be laid down in the horizontal plane, and from thence all the other frames may be laid down in the plane of projection, in the very same manner that the horizontal ribbands and the frames for the after-body were laid down.

C H A P. VII.

General Remarks on Ship Building.

ALL the rules we have hitherto laid down, collected from the principal dimensions of ships built by the most eminent masters, should only be so far regarded as they may assist the artist in forming the body in such a manner as to produce effects answerable to the service for which the vessel is designed.

In order to qualify a builder for such an undertaking, it is necessary he should understand the nature of fluids, and of such bodies as will float in the water; when he has made himself acquainted with these, I would recommend him to Mr *Bouguer's* treatise on ship-building.

The principal Qualities belonging to Ships.

1st. To be able to carry a good sail, not only because in forming the body, the water lines are all supposed to be described when a ship is upright in the water, but likewise for doubling a cape, or getting off a lee shore, which will be impossible to be done when a ship lies over in the water, this will likewise render her lower tier, if not all her guns useless.

2d. A ship should steer well, and feel the least motion of the helm.

3d. A ship should carry her lower tier of guns four feet and a half, or five feet out of the water, otherwise a great ship that cannot open her ports upon a wind, but in smooth water, may be taken by a small one, that can make use of her guns, or she must bare away before the wind, to have the use of her guns; on which account it will be proper to raise the ports higher before than in midships, because the fore part of the ship is often pressed into the water by carrying sail.

4th. A ship should be duly poised, so as not to dive or pitch hard, but go smooth and easy through the water, rising to the sea when it runs high, and the ship under her courses, or lying to under a main-sail, otherwise she will be in danger of carrying away her masts.

5th. A ship should sail well before the wind, large, but chiefly close hawled, keep a good wind, not fall off to the leeward.

Now the great difficulty consists in uniting so many different qualities in one ship, which seems indeed to be impossible; the whole art therefore consists in forming the body in such a manner, that none of these qualities shall be entirely destroyed, and in giving the preference to that which is most required in the particular service for which the vessel is built; in order to
which

which it will be necessary to know, at least nearly, what form will give a vessel one of these qualities, considered abstractly from the rest.

To make a Ship carry a good Sail.

A flat floor timber, and somewhat long, or the lower futtock pretty round, a straight upper futtock, the top timber to throw the breadth out aloft; at any rate to carry her main breadth as high as the lower deck: now, if the rigging be well adapted to such a body, and the upper works lightened as much as possible so that they all concur to lower the center of gravity, there will be no room to doubt of her carrying a good sail.

To make a Ship Steer well, and quickly Answer the Helm.

If the fashion pieces be well formed, and the tuck carried pretty high; the midship frame carried pretty forward; a considerable difference of the draught of water abaft more than afore, a great rake forward and none abaft, a snug quarer deck and forecastle, all these will make a ship steer well; but to make her feel the least motion of her helm, it will be necessary to regard her masts. There is one thing not to be forgot, that a ship which goes well will certainly steer well.

To make a Ship carry her Guns well out of the Water.

It is plain that a long floor timber, and not of a great rising, a very full midship frame, and low tuck with light upper works will make a ship carry her guns high.

To make a Ship go smoothly through the Water without pitching hard.

A long keel, a long floor not to rise to high afore and abaft, the area or space contained in the fore body, duly proportioned to that of the after body, according to the respective weights they are to carry; all these are necessary to make a ship go smoothly through the water.

To make a Ship keep a good Wind.

A good length by the keel, not too broad, but pretty deep in the hold, which will occasion her to have a short floor timber, and great rising.

As such a ship will meet with great resistance in the water going over the broad side, and little when going a head, she will not fall much to the leeward.

Now some builders imagine that it is not possible to make a ship carry her guns well; carry a good sail; and to be a prime sailer, because it
would

would require a very full bottom to gain the first two qualities, whereas a sharp ship will best answer for the latter; but when it is considered that a full ship will carry a great deal more sail than a sharp one, a good artist may so form the body as to have all these three good qualities, and likewise steer well, for which purpose I would recommend somewhat in length more than has been formerly practised.

After what has been said upon this head, I believe it will not be thought impossible to unite all these different qualities in one ship, so that all of them may be discerned in some degree of eminence, but when it happens otherwise, the fault must be owing to the builder, who has not applied himself to study the fundamental rules and principles of his art.

Excepting some antient builders, who were happily born with a natural genius, and our moderns, who being instructed in the principles of the mathematics, have truly laboured very hard to make a progress in the art of shipbuilding, one may, without violating the truth, affirm that the greatest part satisfy themselves with copying such ships as they esteem good sailors, and it is these servile mechanick methods, which to the great reproach of the art, are but too common, that have produced all these pretended rules of proportion, all these methods of describing the midship frame, and forming the rest of the timbers, which every builder endeavours if possible to conceal and keep wholly in his own family.

How low and mean is this? it is as if a great architect should endeavour to conceal the proportions of the different orders of architecture, whereas they are published every where, and so well known that many can raise a very beautifull porch or triumphal arch; but tho' the methods of describing the midship frame and forming the rest of the timbers be known to most apprentices, yet we have but few good master builders: This requires more than those mechanick rules, they should at least have such a knowledge of the mathematics, physicks, mechanicks, of the nature of solids and fluids, as to be able to discover what figure would procure some good quality without hazarding or putting a bad one in its place.

Let us suppose one to have a collection of draughts of a vast number of ships, and whose good and bad qualities have been remarked with all possible exactness, such a valuable treasure would be of great service to a person who could calculate precisely by the draughts where the fault lay, and how it might be rectified. For instance, suppose a ship sails well, but carries her guns too low, a builder who is not acquainted with these principles would raise her deck, in consequence of which she would not sail well; whereas one that could exactly calculate how much the resistance of the fluid is diminished upon the prow, would take great care

to add no more to any of the other parts than he could find by an exact calculation might be done without augmenting the resistance in the fluids.

M. Bouguer has published several useful problems for making these calculations, to which we refer the reader, and only explain what regards the height of the gun deck, and the resistance of the fluid, in one example of a 70 gun ship.

C H A P. VIII.

To know by the Draught how high a Ship will carry her Guns out of the Water.

THIS is only to know if, when a ship is loaded with all her ammunition and provisions on board, and ready to sail, her seat in the water will then agree exactly with the load water line in the draught.

It may be demonstrated by several experiments, that any floating body of whatsoever figure will just sink so far in the water as to displace a bulk of water of equal weight with itself.

Hence it will be necessary, first to find a method of calculating the exact weight of a ship ready equipt for sea, and, secondly, to know the exact weight of the water the ship displaces, when loaded to the water line in the draught.

In order to the first, the exact weight of all the timber, iron, lead, masts, sails, rigging, and in short of all the materials, men, provisions, and every thing else on board the ship must be known.

It must be confessed that this is a very laborious task, yet the zeal of our modern builders has surmounted all these difficulties, and got the exact weight of a ship of each class with all its furniture, and six months provisions on board. It will be sufficient for our purpose to give the particulars, of the two followings, one of 30 and another of 50 guns, both ready equipt for sea, with six months provisions on board.

An Estimate of the Weight of the RENOMEE Frigate of Thirty Guns, with Six Months Provisions.

WEIGHT of the HULL.

	Cubic feet	Under water Pounds.	Above water Pounds.	Total in Tuns.	
				Tons	Pounds
Oak timber { under w. at 72 lb. per f.	5640	406080	192720	299	800
ber { above w. at 66 lb.	2920				
Fir at 50 lb. per foot { under water	600	30000	28000	29	000
{ above water	560				
Carved work			2200	1	200
Iron knees and standards		4200	7010	5	1210
Bolts, rudder irons, chain plates, nails		11650	6558	9	208
Lead for the hause holes & scuppers		250	430	0	680
Locks			170	0	170
Oakum		1200	1830	1	1030
Pitch and Tar			650	0	650
Paint			440	0	440
In the Cook room			8000	4	000
Total		453380	248008	350	1388

WEIGHT of the FURNITURE.

	Pounds.	Pounds.	Tons	Pds
Masts compleat set and spare	3000	37000	20	00
Blocks	1000	5444	2	444
Pumps	1734	670	1	404
Cables and Hawfers	24444		12	444
Sails and their Cafes	4222	3778	4	000
Anchors and their Stocks	2611	6944	4	1555
Cordage for the rigging		17282	8	1282
The master's Stores	3333		1	1333
Boats		6666	3	666
	40344	75784	58	128

WEIGHT of the PROVISIONS, &c.

	Under water Pounds.	Above water Pounds.	Total in Tuns.	
			Tons	Pounds
Provisions for 6 months for 200 men with all their equipage	245420		122	1420
Water for two months and a half	100000		50	000
Casks	32800		16	800
The Captain's table	15000	5000	10	000
Total	393220	5000	199	220

WEIGHT of the OFFICERS STORES.

	Under water Pounds.	Above water Pounds.	Total in Tons	
			Tons	Pds
The Carpenter's Stores	3000	1000	2	00
The Caulker's Stores	1000		0	1000
The Surgeon's Effects	2400		1	400
The Pilot's Effects	740	360	0	1100
The Chaplain's Effects		100	0	100
	7140	1460	4	600

WEIGHT of the GUNS and AMMUNITION.

	Under water Pounds.	Above water Pounds.	Total in Tons	
			Tons	Pds
Iron Guns		60300	30	300
Carriages fitted		14000	7	00
Balls round and cross bar	11570	2430	7	00
Balls of one pound	600		0	600
Powder and Powder Barrels.	7108	112	3	1220
Implements for the powder	1368	132	0	1500
Crows, Handspikes, Gunners Utensils, and Stores	3200	1500	2	700
Musquets, Cutlasses, and Pole Axes		900	0	900
	23846	79374	51	1220

WEIGHT of the MEN and their EQUIPAGE.

	Under water Pounds.	Above water Pounds.	Total in Tons.	
			Tons	Pounds
8 principal Officers and their Effects		4000	2	00
200 Men and their Effects		40000	20	00
Total		44000	22	00
BALLAST	200000		100	00

RECAPIT-

RECAPITULATION.

	Under water Pounds.	Above water Pounds.	Total in Tons.	
			Tons	Pounds
The Hull	453380	248008	350	1388
The Furniture	40344	75784	58	128
The Provisions	393220	5000	199	220
Officers Stores	7140	1460	4	600
Guns and Ammunition	23846	79374	51	1220
Weight of the Men		44000	22	00
Ballast	200000		100	00
Total	1117930	453626	785	1556

An Estimate of the Weight of a Frigate of Fifty Guns, with Six Months Provisions.

	Under water Pounds.	Above water Pounds.	Total in Tons.	
			Tons	Pounds
The Hull	774270	769134	771	1404
The Furniture	98237	163184	130	1421
Ballast	300000		150	000
Guns and Ammunition	67960	199320	133	1280
Provisions	659400	8000	383	1400
Stores	9800	2800	6	600
Men and their Equipage		77000	38	1000
	1909667	1219438	1564	1105

But as all ships of the same class are pretty near the same dimensions, and have the same number of guns, &c. we may have the exact weight of each only by examining the draught of water, and computing the weight of that column of water which is displaced by the ship.

Now if the *Intrepide* weighs 2718 tuns, she must sink so far into the water till she has displaced a column of water containing $73459\frac{17}{37}$ cubick feet, for a cubick foot of salt water being supposed to weigh 74 lb. the $73459\frac{17}{37}$ will weigh 5436000 lb. or 2718 tuns, or if she displaces $73459\frac{17}{37}$ cubick feet of salt water, we may thence conclude that she weighs 2718 tuns.

In like manner, if the weight of the ship which is to be laid down in the

the draught be known; as, for instance, that of a ship of 78 guns, is 2350 tuns, we may with certainty know if the water line in the draught be properly placed, only by reducing the bottom into cubick feet.

The antient builders were unacquainted with the manner of performing this, but our moderns make an exact calculation of the contents of the bottom before they begin to build, whereby they will be sure to keep the lower tier of guns well out of the water.

If a ship's body were any regular figure, the solid contents of it could easily be found geometrically, but as the case is quite otherwise, we must be satisfied with dividing it into several parts, of which we may have a great number, and they will thereby become so small, that they may, without any sensible error, be esteemed as regular figures, limited by straight lines, tho' some of them are actually curves.

In the draught of the 70 gun ship which we have laid down, the bottom is divided on the plain of elevation into several parts, in a vertical way by the lines that represent the frames; and in an horizontal way by the water lines, so that the whole may be said to be divided into so many parallel pipedons, A, B, C, D , or a, b, c, d , contained betwixt the two frames 6 and 7, and limited on the side AB by a plain supposed to be erected vertically upon the keel, and on the other side by the round of the outside of the ship, at the height of the breadth water line, or ac . Now it is very plain that the area of the surface, which limits the lower part of this solid, is less than the area of the surface, which limits the upper part: But if we increase the water lines, and frames we may find the solid contents to a sufficient exactness for our purpose.

Now, in order to find the area of the upper surface $ABDC$, let AC be 16 feet 11 inches, and BD 13 feet 6 inches; add these two, the sum is 30 feet 5 inches, the half of which is 15 feet two inches and a half, and this sum multiplied by AB , which suppose 8 feet, the distance betwixt the frames, the product is 121 feet 8 inches, the area of the upper surface of the parallel pipedon.

The area of the lower surface of the parallel pipedon may be found after the same manner, which suppose 97 feet 4 inches. Now, if these two areas be added together their sum will be 219 feet, the half of which is 109 feet 6 inches for the mean area, and this multiplied by ab , the distance betwixt the water lines, which suppose 4 feet 4 inches, produces 474 feet 6 inches cubick.

By the same process we may find the solid contents of the other parallel pipeds, and adding them together, and doubling that sum we shall have the

the solid content of the whole bottom of the ship in cubick feet to a sufficient degree of exactness.

I made use of this method before Mr *Bouguer's* treatise was published, where there is one which is more convenient and expeditious, for instead of finding the area of every single surface contained betwixt the frames upon the section of a water line, he finds by one operation the area of the whole surface formed by the horizontal section or water line, except that part intercepted betwixt the aftermost frame and the post, and the part contained betwixt the the foremost frame and the stem, which upon account of the rake must be measured separately, as also all that lies betwixt the upper side of the keel and the first water line. His method is as follows:

Take the lengths of all the lines that represent the frames on the horizontal plane, add all these together, excepting the foremost and aftermost, of which take only one half of each, so if it were required to find the area of the surface formed by a horizontal section in the plane of the load water line, it will be $\frac{1}{2} ZZ + BD + AC + IH + LK$, &c. $+ \frac{1}{2} XS + AB$, supposing AB to be the distance betwixt the frames equally spaced betwixt ZZ and NO.

To demonstrate this, let it be considered by what operation the two trapezia ABDC and HIAC are measured. We observed in the preceeding article that this was performed by adding the length of the lines BD and AC together, and then taking half that sum; the length of the lines AC and HI, must likewise be added together, and the half of that sum taken; now it is evident that it will be same thing to take half the line BD, and half the line HI, and the whole line AC, and add all these three together, because the line AC, is common to both the trapezia.

After the areas of all the water lines are thus found, the solid content of the space contained betwixt the water lines may be had by multiplying the area by the distance between the water lines: But because the areas of the two surfaces which limit this part are unequal, a mean area must be found; this is half the sum of the two areas, so that all that is now to be done, is to add the areas of the water lines into one sum, excepting that of the upermost and lowermost, of which only one half of each must be taken, and if this sum is multiplied by the distance betwixt the water lines, the product will give half the solid content of the bottom, observing that the water lines in the plain of elevation be equally distant from one another.

The application of this method in finding the cubick feet contained in a 70 gun ship laid down in the draught.

The

The forepart is divided into eight, and the after into nine equal parts, besides that betwixt the aftermost timber and the post, and that betwixt the foremost timber and the stem.

The bottom is likewise divided into four equal parts by water lines drawn parallel to the load water line, all which are formed upon the horizontal plane, for it will be very useful to know the solid content of each particular part contained betwixt the water lines, also to distinguish that of the fore body from the after body, whereby we may be enabled to know if the weight be duly poised. We shall consider all this in the following calculation.

Note, there must be four inches added to each line that represents the frames in the horizontal plane for the thickness of the plank, that being nearly a mean betwixt the thickness of the plank next the wale, and that next the keel.

The Area of the Upper Water Line abaft.

The breadth of the surface at the load water line, upon the midship frame *a Q* is 21 feet 2 inches,

		feet.	inch.
	one half is	10	7
Breadth at	1st Frame	21	2
	2d Frame	20	11
	3d Frame	20	9
	4th Frame	20	5
	5th Frame	19	11
	6th Frame	18	11
	7th Frame	17	4
	8th Frame	15	7
The 9th Frame <i>X S</i> is 12 feet 9 inches, one half of which is		6	4½
Total		171	11½

which total doubled is 343 feet 11 inches, and multiplied by 8, the distance betwixt the frames, is the whole area of the water line from the midship to the after frame, in cubick feet } 2751 4.

To this must be added the area of the trapezium *X S L e*

Now half of the lines *X S* and *L e* is 10 Feet 0 Inches

Distance betwixt them is

$$\begin{array}{r} \text{Product is } 97 \frac{9}{6} \\ \text{which being doubled is } 195 \frac{0}{6} \\ \text{The whole area in cubick feet } 2946 \frac{4}{6} \end{array}$$

By using the same process we may find the areas of all the other water lines, and adding all these areas together, excepting that of the first and fifth, of which taking only one half, multiply this sum by 4 feet 5 inches, which

which is the distance betwixt them, we shall have the area in cubick feet of that part of the ship abaft the midship frame, contained betwixt the lower water line, and load water line.

	feet	inch.	l.	p.
Half the area of the load water line	1473	2	0	0
Whole area of the 4th water line	2516	1	4	0
Whole area of the 3d water line	2052	0	4	0
Whole area of the 2d water line	1452	10	7	6
Half the area of the 1st water line	144	3	2	0
Total	7638	5	5	6
Multiplied by the distance betwixt the water lines	4	5	0	0
Product in cubick feet betwixt the lower, and load water line	33736	6	1	3 6
Betwixt the lower water line and keel	333	6	3	0 0
Keel and post	101	8	0	0 0
Cubick feet abaft the midship frame under water, when loaded	34171	8	4	3 6
Cubick ft. before the midship frame under water, when loaded	28928	6	1	0 0
Total cubick feet under water	63100	2	5	3 6
Multiply by the weight of a cubick foot of salt water		pounds	tuns.	lb.
Weight of the whole ship with all her furniture } provisions &c.	4661498	2334	1498	

We have omitted the operation for the fore part, because it is performed exactly by the same method with the after part.

It must be observed that in finding the cubick feet of that part contained betwixt the lower water line and upper side of the keel, we must take the heights of all the frames intercepted betwixt these two lines, and divide their sum by the number of frames abaft the midship, the quotient will be 1 foot 9 inches 9 lines.

	Feet	In.	Lines
The area of the lower water line is	288	6	4
The area of the upper side of the keel	79	6	0
Total	368	0	4
one half is	184	0	2
Area of that part contained betwixt the lower water line and keel	333	6	3

The use of the preceeding calculation is to know if the load water line upon the draught be properly placed.

It has been found that a ship of 70 guns, with every thing on board, should weigh nearly 2350 tons, which is only 15 tons 1297 pound more than what is found by calculating from the load water line in the draught, this difference would occasion the ship not to draw above one inch more water

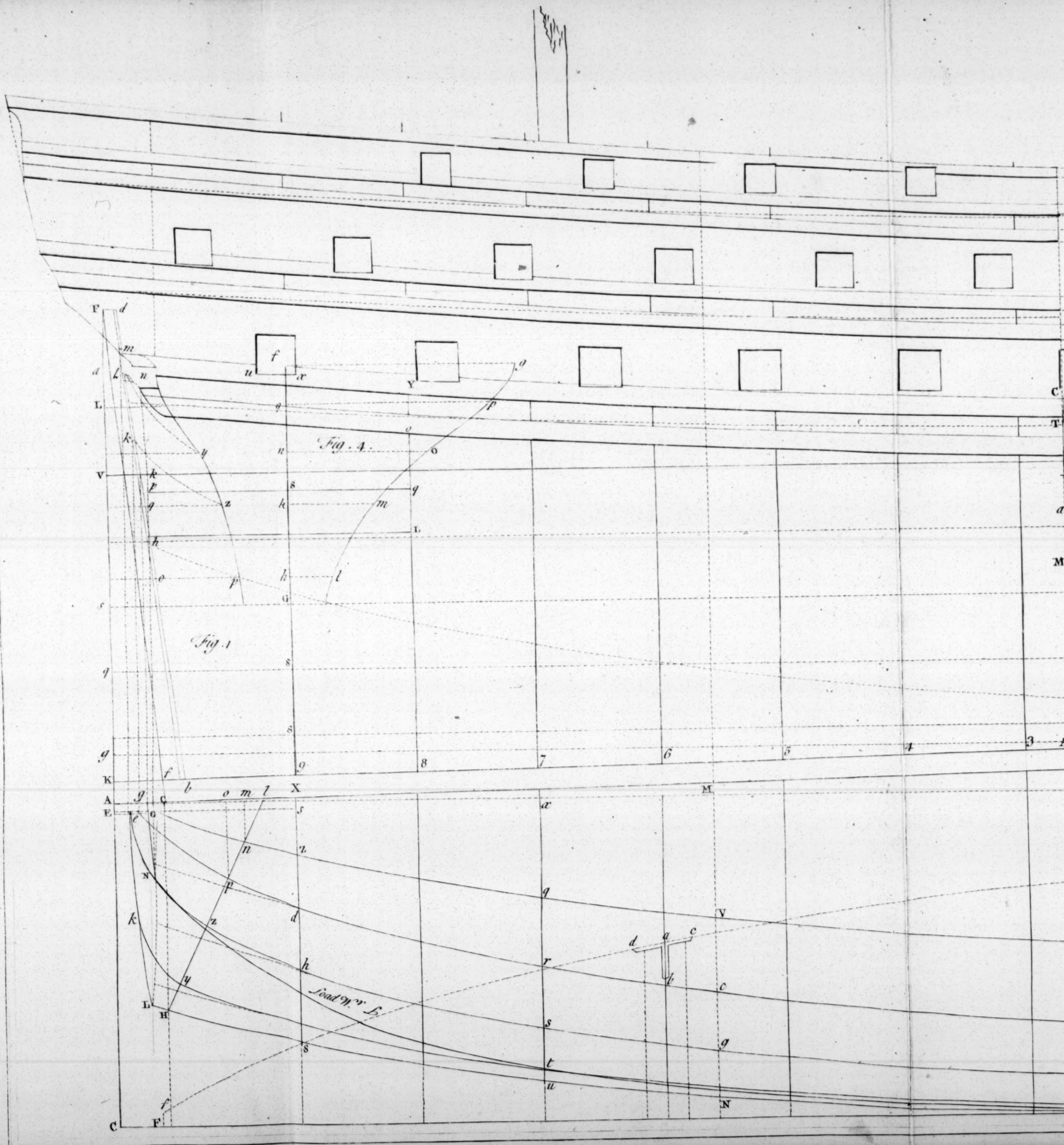


Fig. 3.

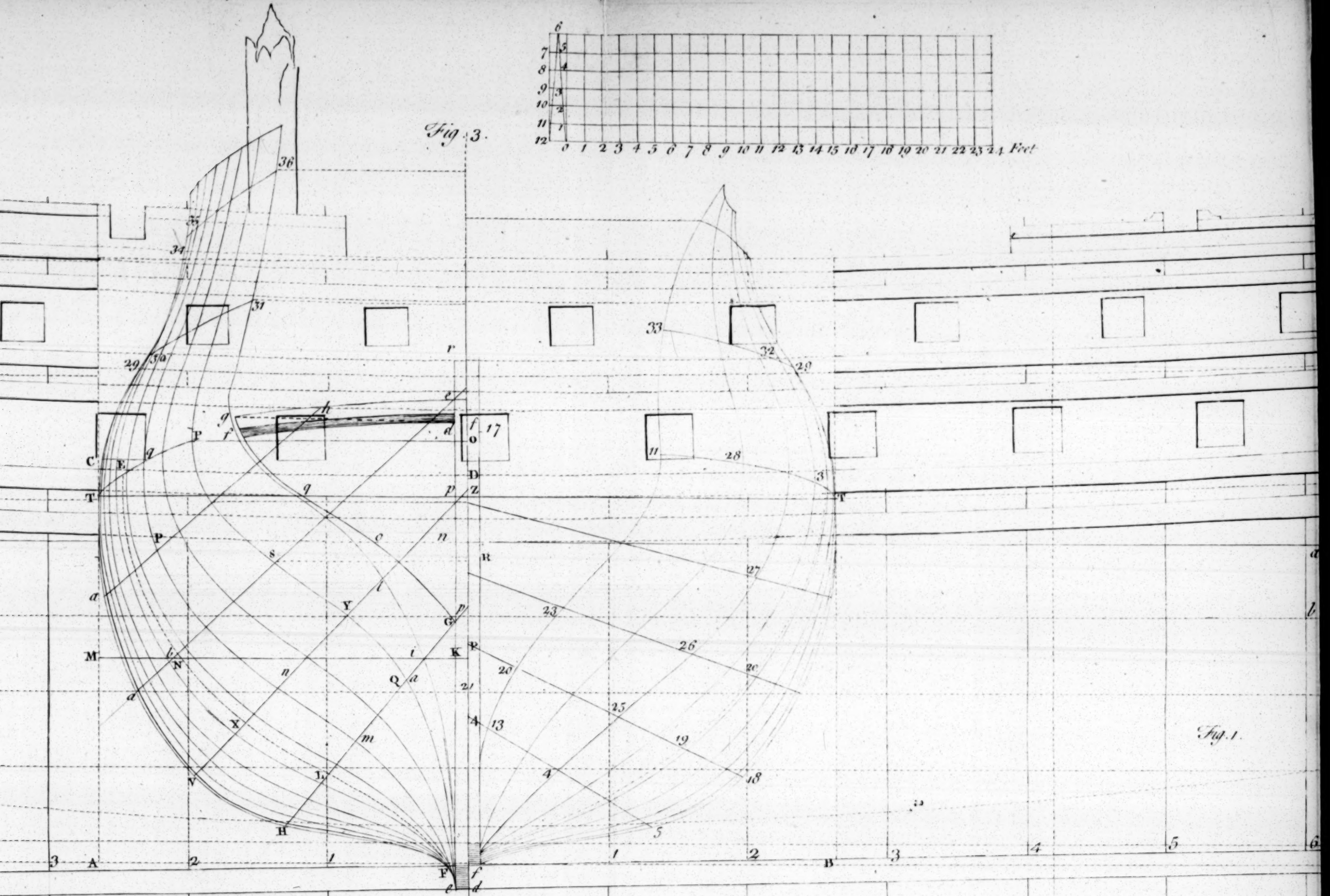
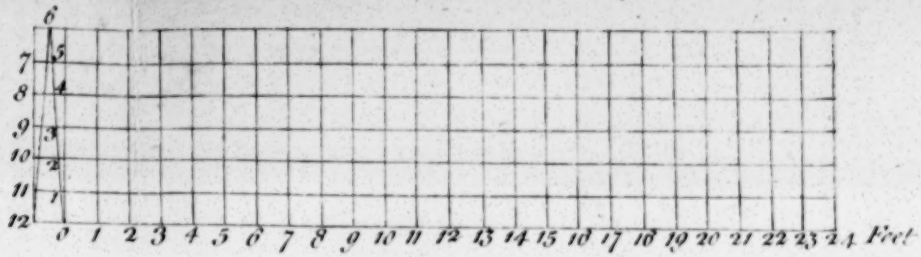
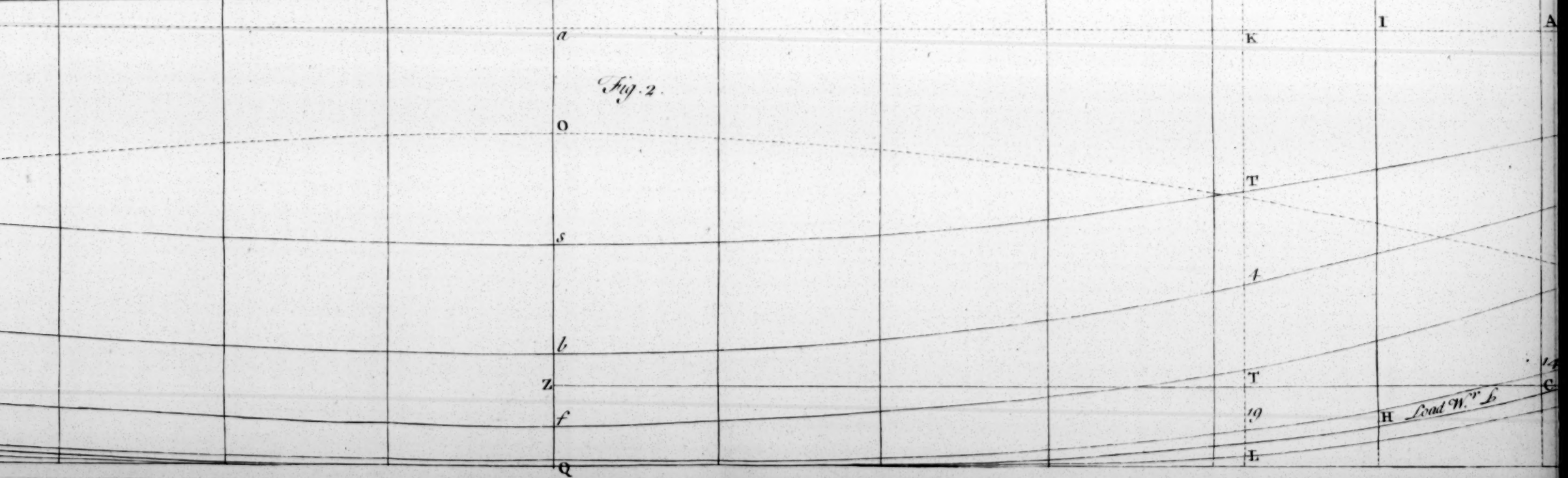
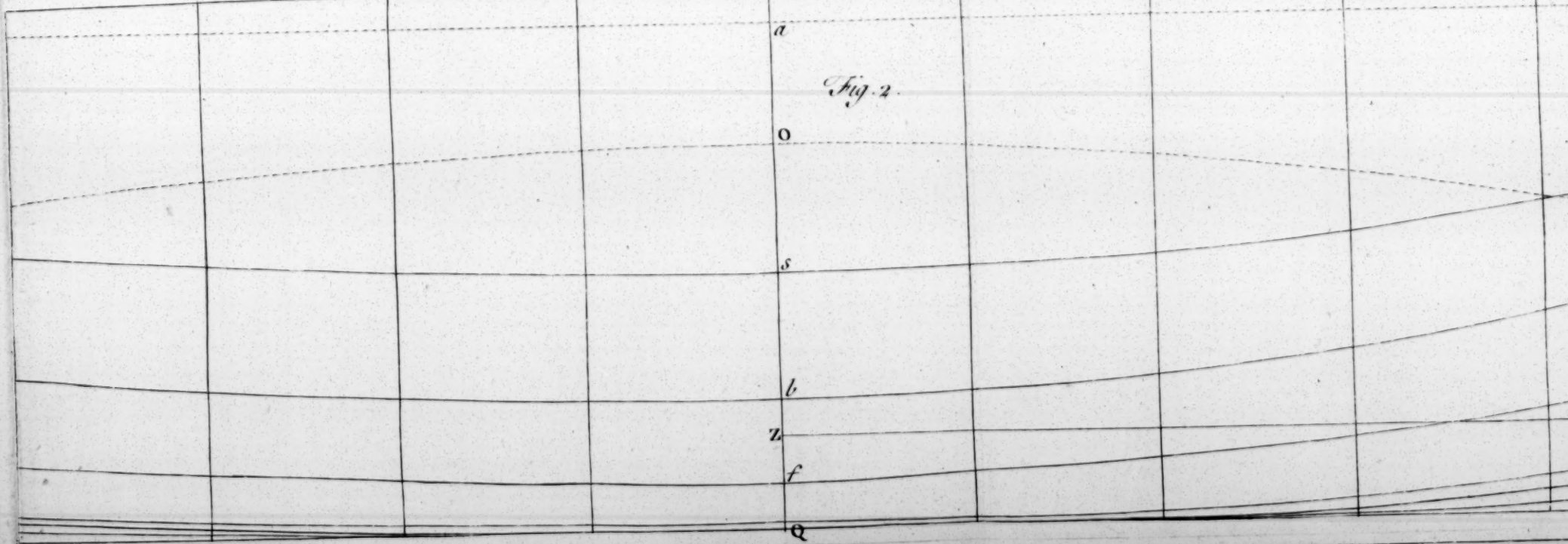
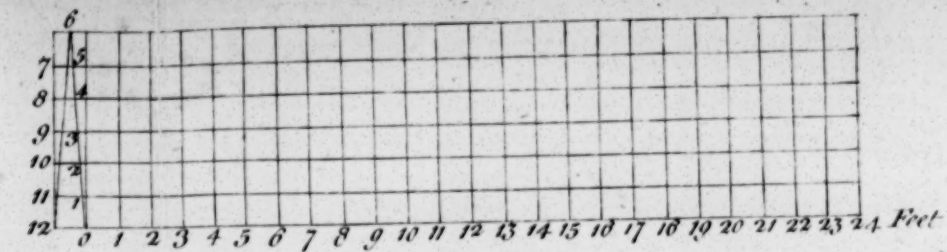
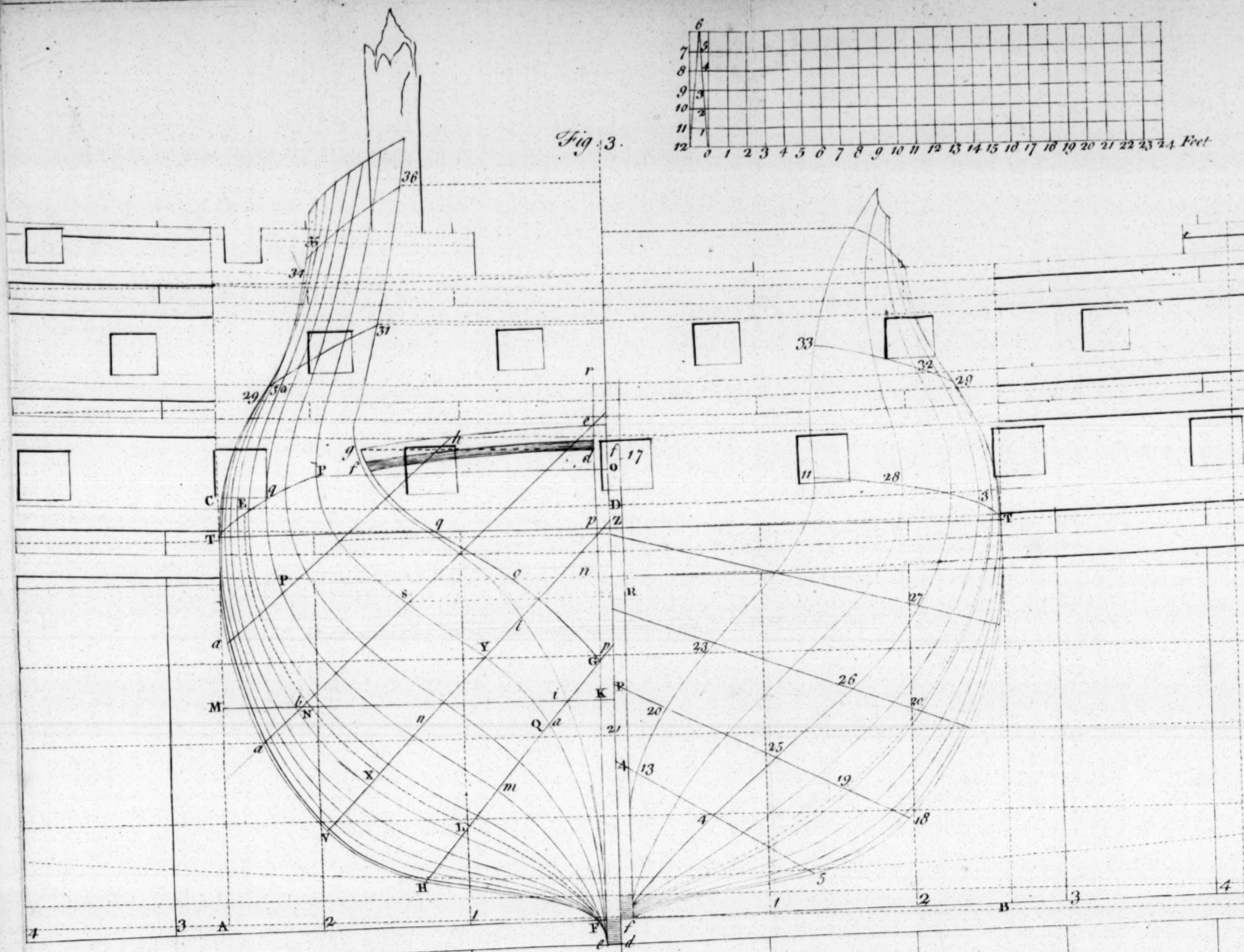
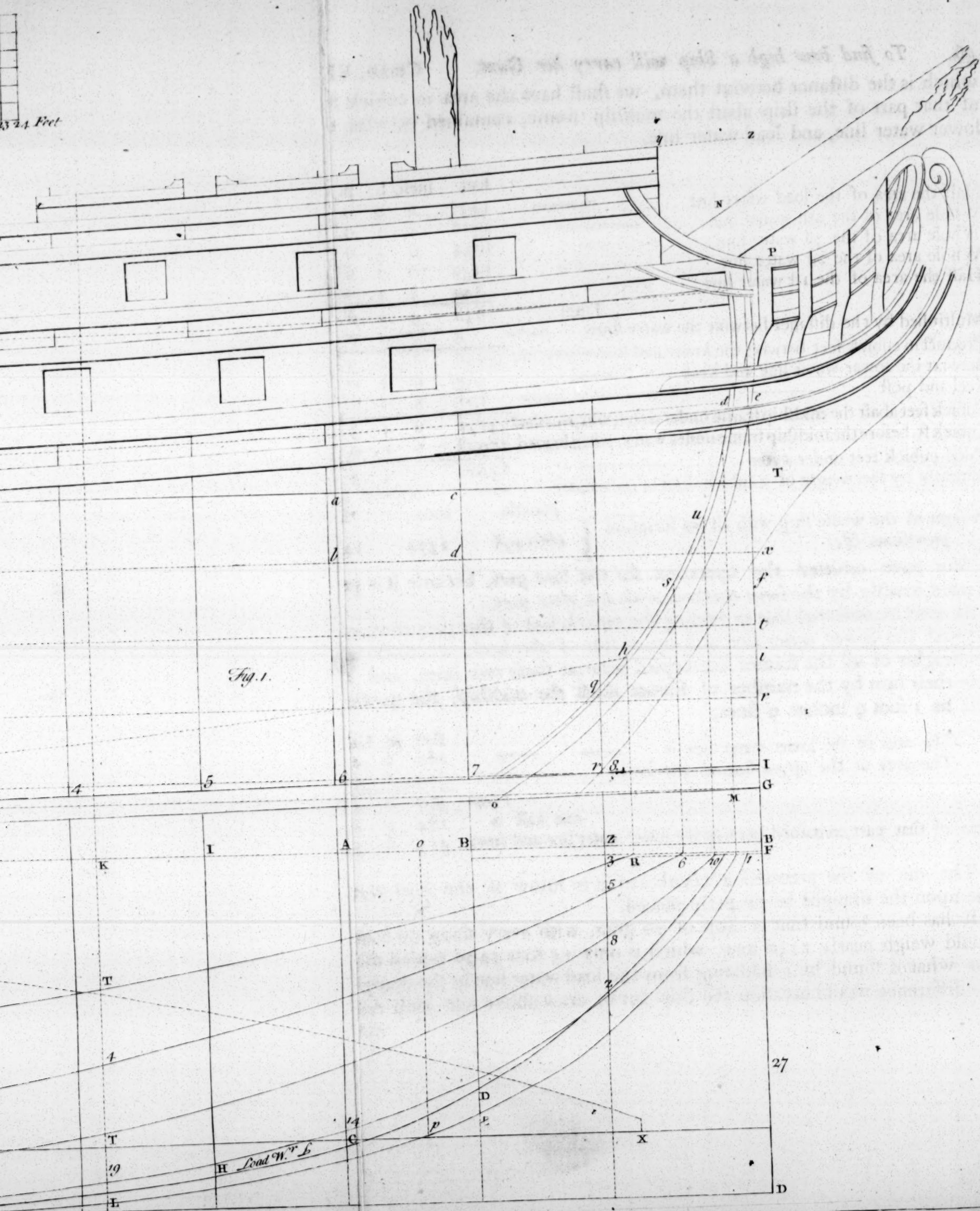
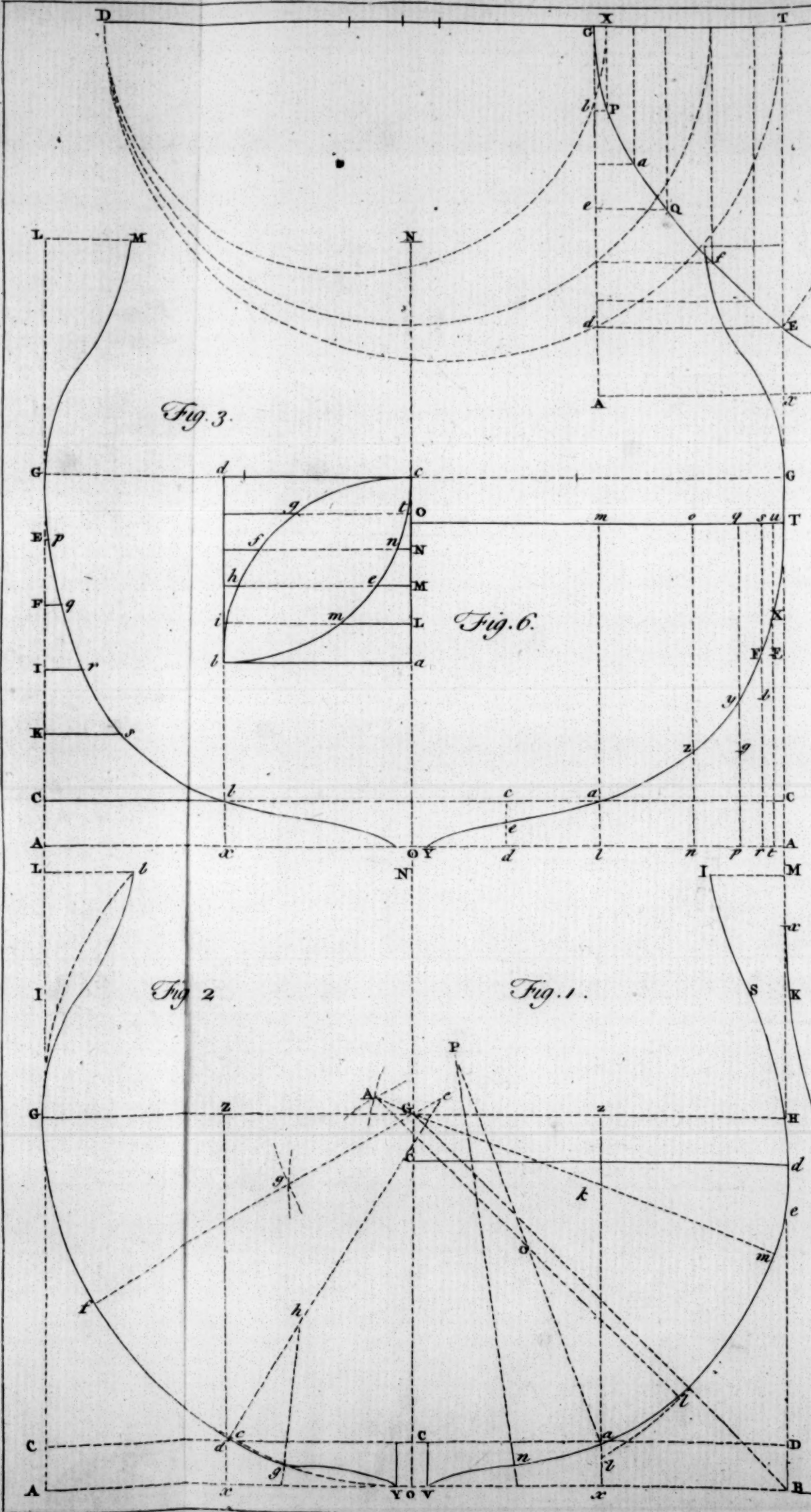


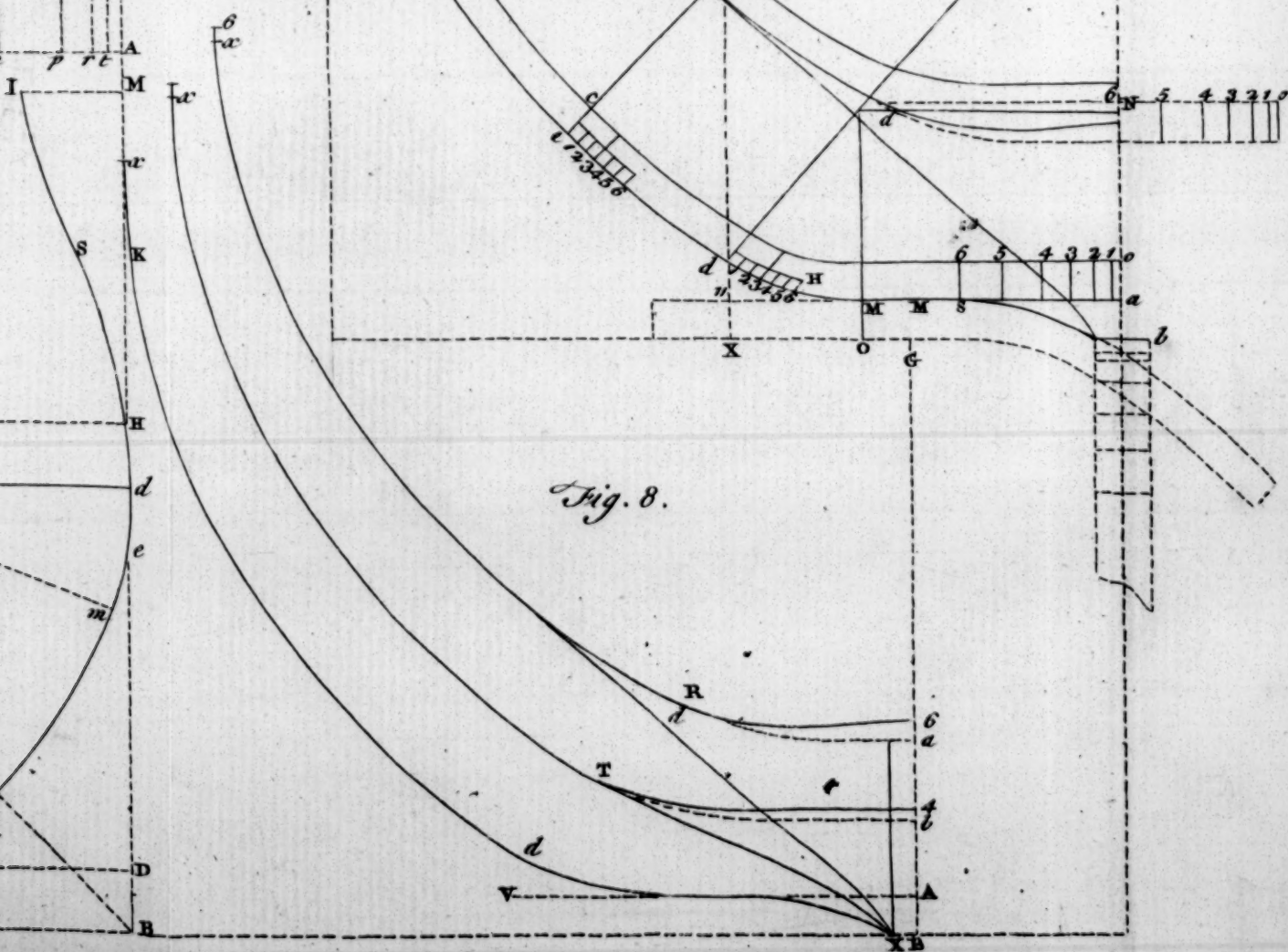
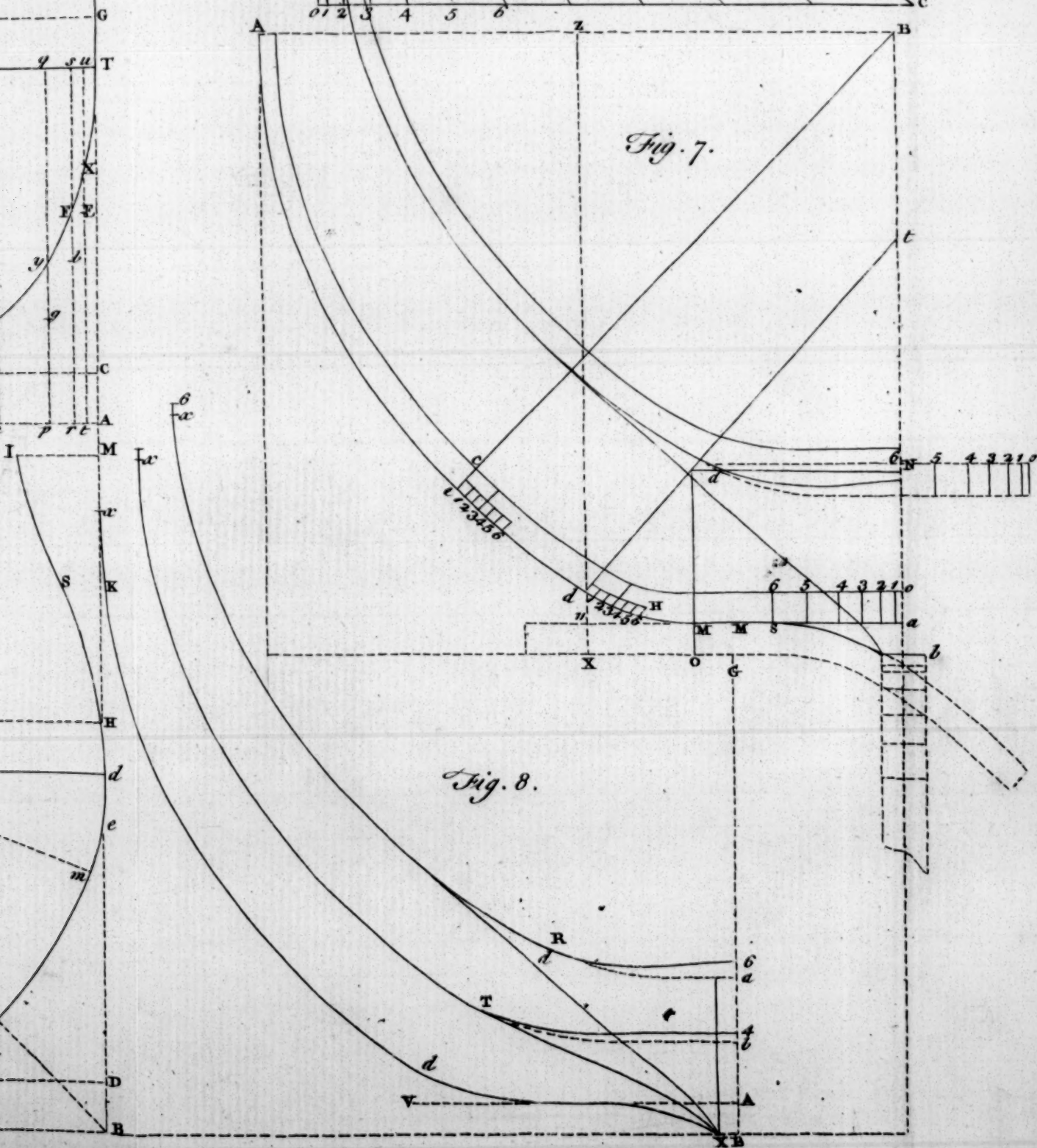
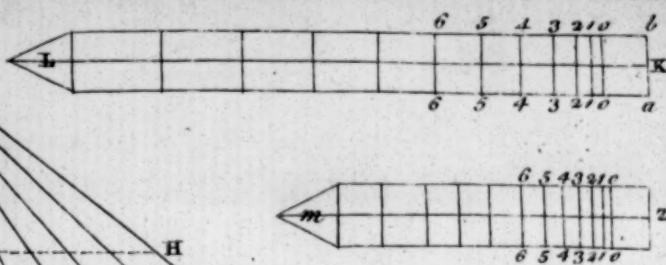
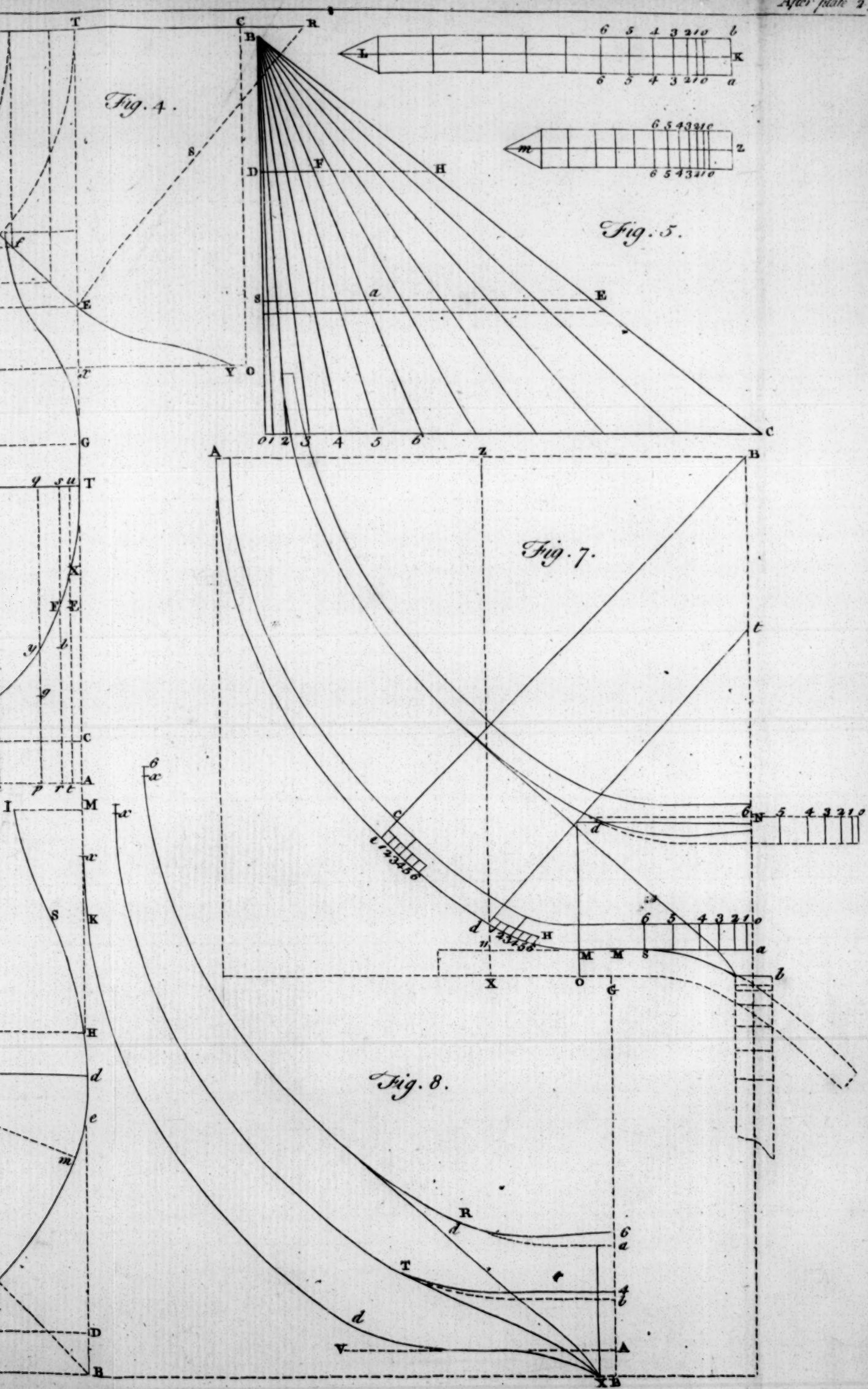
Fig. 2.











water it is not worth the regarding. But then by this calculation we discover that the ship is too lean before; for whereas the fore part should exceed the after part by 30 tons, we find, by this calculation, that the after part exceeds the fore part by 193 tons 1995 pounds.

Upon this account we must consider carefully if the midship frame is properly placed; it is here 5 feet before the middle. If the midship frame was exactly in the middle it would augment the weight of the fore part 102 tons 307 pounds, and diminish that of the after part exactly the same quantity, by which means the fore part would be 1172 tons 1014 pounds, and the after part 1162 tons. Now we may fill out the fore part, so as to gain 15 tons 636 pounds, which was deficient, to make the calculation taken from the draught agree with the real weight proposed for a ship of 70 guns fitted out for sea, with six months provision on board; and the fore-body will weigh 25 tons 1255 pounds more than the after part, which may be judged sufficient.

C H A P. IX.

A method to calculate the Resistance of the Water upon the fore Part of the Ship.

DAILY Experience sufficiently proves that the fluids, by their motion, attack the solids that oppose them, as bridges, mills, &c. with such violence as to carry all before them; and this is agreeable to the very nature of fluids.

For all fluids are an assemblage of a prodigious number of small solid bodies of a globular form, each of which being easily put in motion will act upon any surface with the same force that any other solid body of the like mass would do. But as these particles have but a very small cohesion with each other, fluids cannot act with the same force as solids which have their parts united.

A mass of water of 20 cubical feet will not act with the same force upon the pier of a bridge which opposes it, as a mass of ice of the same dimensions; because the whole mass of ice having its parts so united together, that one cannot advance without the other, it gives the blow with the united force of all the parts at once, whereas the parts that compose the mass of water, being but slightly united, they cannot act jointly or in concert, and they exert their force one after another; they indeed succeed one another immediately, and are a little united by their reciprocal pressure;

sure ; but as every part has its own peculiar velocity, so it makes its effort singly by itself, and, being easily put in motion, it will be as easily turned out of its direction, the parts being only retained together by the weight of those that come next them.

Fluids have a continual effort, because when a certain number have produced their effect they are succeeded by others as long as the current lasts.

Hence it will follow, that when a vessel is left to a current of the river, it can receive no more velocity than the current has, and its velocity will be accelerated till it is equal to that of the current.

If, on the contrary, any floating body receives a motion in a contrary direction to that of the current, it will be continually retarded, till it has none, and then it will change its direction to follow that of the current.

We shall here remark, that it is indifferent whether we ascribe the motion to the solid or to the fluid ; for the impression of the water upon the ship's stem is the same when under sail, as when at an anchor, provided the motion of the current be equal to that which the ship acquires by sailing.

The effort of fluids is as the square of the velocity of the current.

It is very plain that the more rapid the current is, the greater will the impression of the fluid be ; for the parts will then shock the solid with greater force than when it runs slowly ; so that the force is augmented in proportion to the velocity. Again, the number of the parts of the fluid that strike the solid in any space of time, is in proportion to the velocity of the current ; for the faster it runs the greater will be the number of the parts that strike the solid in a space of time ; so that not only the effort of the fluid, but likewise the number of parts that attack the solid, is augmented in proportion to the velocity of the current, and when these two are united, the effort of the fluid will be in a duplicate ratio of the velocity ; so that if the velocity be doubled, the shock will be quadrupled.

Hence, the faster a ship goes through the water, the greater will be the resistance she meets with, and this will be augmented in a duplicate ratio of the velocity with which she sails.

The impression of a fluid increases as the surfaces which oppose its current.

It is very plain, that if one surface is double another it will receive double the number of the parts of the fluid, and of consequence the impression will be double upon a surface, whose area is double the area of another surface. Hence those ships whose midship frames have the greatest capacity meet with most resistance.

The efforts of fluids will be less when the surfaces are in an oblique position to the current, than when in a perpendicular position.

Plate

Plate IV. Fig. 7.] Let EA represent the course of the fluid setting perpendicularly on any body AB ; it is plain, that it receives the impression of all the parts of the fluid contained between A and B ; whereas, if the point B be moved to D , the parts of the water contained betwixt B and G will have no impression upon AD . Hence the quantity of the fluid which attacks AB is to that which attacks AD as AB is to AG ; that is, as the radius is to the sine of the angle of incidence EAD . But if there were no other advantage gained by this oblique position, than being exposed to fewer parts of the fluid, it would be of very little service to a ship which must have a sufficient breadth, suppose AB ; it is plain, the number of the parts of the fluid which give the impression will be the same, when the fore part of the ship is in the form of ADB , as when it is flat in the form of AB ; but the fluid which exerts its force on the surface ADB does not produce the same impression as when it exerts its force on AB , because the direction of each particle of water, which strikes any surface obliquely, may be resolved into two directions, one perpendicular, and the other parallel to the plane.

In order to give us an idea of compound motions, and of the resolution of their forces, let us suppose two rulers AA and BB , (*Plate IV. Fig. 5.*) placed upon a plane at right angles to one another, and a small ball C placed at the angle of their meeting, it is plain, if we slide the ruler BB in a parallel position to itself, it will carry the ball C along the edge of the ruler AA ; but if both the rulers be made to slide together, so that they still preserve the same angle, in such a manner that when the ruler AA arrives at the line VII , VII , the ruler BB arrives only at the line 3 , 3 . It is plain, the ball will describe the diagonal of the parallelogram C , VII , D , 3 , the sides of which will be proportional to the distance the rulers have moved, that is, $DVII$ is to $D3$ as 3 to 7 ; but if the rulers be supposed to be moved equally, so that when AA arrives at the line VII , VII , BB shall arrive at the line 77 , the ball will describe the diagonal CF of the square $CVII$, $F7$.

Now, if we substitute any other two agents in the place of the rulers, such as two hammers, and both be supposed to strike the ball with equal force at the same time, it is plain, the ball will go in the direction of the diagonal CF ; but if the force with which one hammer strikes the ball be to that by which the other hammer strikes the ball, as 7 to 3 , then the ball will move in the direction of the line CD .

The principal Effects of Compound Motions. (Plate IV. Fig. 6.)

If two powers C and B act with equal force on the body A, but in the contrary directions of the lines C A and B A, the body A will remain at rest; but if one of the powers acts with greater force than the other, the body will follow the direction of that which predominates, diminished by the quantity of the smaller force.

2d, If two powers D and E act upon the body A in the same direction, viz. in the lines D A and E A, the body A will follow the direction of both, and pass through the point F, with this only difference, that it will go with greater velocity when impelled by both powers than with one.

3d. Let the two powers G and H strike the solid A, in the direction of the lines G A and H A, it will thereby receive a compound motion, the force and direction of which may be expressed by the diagonal of a parallelogram, as was before observed.

In order to construct this parallelogram, which is called the *resolution* of the forces, let the two powers G and H be supposed equal and expressed by the lines H A and G A; from the point G draw the line E G equal and parallel to H A, and the diagonal E A (the result of the two powers represented by the sides of the parallelogram H A and G A) shall express the velocity and direction of the compound motion; the effect of which will be, that the body A will be carried to the point F. But supposing the forces unequal, and let that of H, (*Fig. 9*) represented by the line H A, be double that of G, represented by the line R A; then from the point R draw the line R S equal and parallel to H A, which shall express the force and direction of the power H; and from the point H draw the line H S parallel to R A, which will express the force and direction of the power G; the diagonal S A expresses the velocity and direction of the body A, which will pass through the point T, whereas, if the powers were equal, it would pass through the point F.

It may be remarked, that two attractive powers placed at P and Q, would produce the same effect as two impulsive powers at G and H, and that the parallelogram may be constructed on the lines A Q and A P.

C O N S E Q U E N C E S.

1st. The acuter the angle of the direction of the power is, the nearer will they approach to one direction, and act with greater force; so the result of G and H is greater than that of K and I, supposing the powers to be equal.

2d,

2d. The greatest effect of two powers is, when they both act in the same direction, and the least when they act in contrary directions.

3d. When two equal powers act in such a direction that they form an angle of 120 degrees, as AK and AI ; in this and in no other case, the result will be equal to the single force of AI or AK ; it only changes the direction; for when the two powers act jointly, A will be carried to F , whereas if K only acted, it would be carried to T ; or if I only acted, A would be carried to V .

4th. If the direction of two powers make an angle less than 120 degrees, as GA and HA , they will assist one another; but if they form an angle greater than 120 degrees, as LA and AM , they will be reciprocally diminished.

The Results of a Motion impressed upon a Body A , in Relation to a Surface ab , which opposes its Motion. (Plate IV. Fig. 6.)

1st. When a body strikes a surface obliquely it will be with less force than when it strikes it perpendicularly; for it may strike it so obliquely as only to graze along it; between the perpendicular shock, which is the greatest, and the oblique, which approaches nearest to a parallel to the surface, there may be an infinite number of directions, less or more oblique, and the surface will be struck with more or less force.

2d. If the two powers are united in D , they will act, in the direction DF , with great force upon ab , because they not only act jointly, but likewise in a perpendicular direction upon the surface ab .

3d. If the two powers be equal in force, and act in the direction of the lines GA and HA , the body A will also fall perpendicularly on the surface ab , but with less force than in the first case, because of the obliquity of the directions.

4th. If the power H have double the force of the power G , then the direction will be changed into the line SA , (*Fig. 9.*) and the body will strike the surface obliquely in the direction of the line ST , but with less force than in the second case, not only on account of the diminution of the force of the power G , but also on account of the obliquity of the shock.

5th. It will be indifferent whether the body A receives its impulse from one single power, or from two, so that it strikes the surface ab in the same direction. Hence we shall have no occasion to consider the powers which give the motion, but only the velocity and the direction in which they strike the surface.

6th. It will produce the same effect, whether we change the line of direction

direction, in which the body *A* strikes the surface *ab*, or change the position of the surface *ab* in respect of the line of direction.

From what has been said, it will follow, that if the common effect of two powers acting upon the same body be known, and also the direction and force of one of them, then the direction and force of the other may be found; for let the body *C* (*Fig. 5.*) be carried to the point *D* by the action of two powers, and one represented by the line *C, VII*; draw the line *D 3* equal and parallel to *C, VII*, and compleat the parallelogram, so shall *C 3* express the force of the other power.

The Application of what has been said to the Shock of Fluids.

We have hitherto considered the shock of a solid body in different directions upon the surface of another solid, but we will readily grant that fluids do not act in the shock in the same manner that solids do. It is very probable, that when a fluid falls perpendicularly upon a surface, there is a mass of water that rests immoveable before the surface, which occupies the place of a solid body, and has nearly the same effect as if the surface was round, so that the fluid does not attack the body that opposes it in a direction perpendicular to its course; besides, the particles of water which attack a surface, whether obliquely or not, may rebound and change their direction, so that the laws of fluids are quite different from the laws of solids in the shock.

The oblique direction of a particle of water may be resolved into one that is perpendicular to the body which opposes its course, and one that is parallel to it.

In order to construct this resolution, (*Plate IV. Fig. II.*) upon the line *AC* inclined to the current, form the parallelogram *AHEF* (*AE* representing the velocity and direction of the current) making *EF* parallel to *CA* and *EH* perpendicular to *CA*. The diagonal *EA*, which represents a particle of water and its velocity, will be the result of a motion supposed to be produced by two powers, one parallel to *AC*, whose force and direction is represented by *EF*, the side of the parallelogram.

Hence it will follow, that when a surface is exposed to the shock of a current, in different oblique directions, the force of the direct shock is to that of the oblique, as the square of the radius is to the square of the sine of the oblique angle of incidence; for the effort of the particle *EA*, which strikes the body *AB*, in a perpendicular direction, is to the effort of the same particle of *EA*, which strikes the body *AC* in an oblique direction, as *EA* is to *EH*; but *EA* is to *EH* as *AB*, the sine of the right angle,

angle, is to AG , the sine of the oblique angle of incidence. But it was before observed, that the sum of the particles that strike AB is to the sum of the particles that strike AC as the radius is to the sine of the angle of incidence. Hence, by multiplying the effort of one particle, by the number of particles that strike AB ; (that is, the effort of the whole water upon AB) and multiplying the effort of one particle, by the number of particles that fall upon AC , (that is, the effort of the whole fluid upon CA) we shall have the following proportion: The effort of the whole fluid upon AB is to its effort upon AC as the square of the radius is to the square of the angle of incidence.

When the surfaces AB and AD , which oppose the current AE , are unequal (*Plate IV. Fig. 10.*) the quantities of water which strike these surfaces are as the product of the surfaces by the sines of the angles of incidence; from whence we shall have the following proportion: The effort of the fluid upon AD is to that upon AB as the square of AG , the sine of the angle of incidence multiplied by the surface AD , is to the square of AB the radius, multiplied by the surface AB .

CONSEQUENCES.

1st, If two equal surfaces, exposed to the same current, receive its shock in different obliquities, the impressions will be to one another as the squares of the sines of the angle of incidence.

2d. A surface parallel to the current can receive no shock, because there is no angle of incidence.

3d, If two unequal surfaces are exposed to the same current, the impressions they receive by the shock in different obliquities, are to one another as the products of the squares of the sines of the angles of incidence, and of the surfaces that receive the shock.

4th. If two equal surfaces receive the shock of two unequal currents, the impressions will be to one another as the products of the squares of the velocities, and of the squares of the angles of incidence.

5th. If two unequal surfaces are exposed to two unequal currents, which strike them with different obliquities, the impressions will be to one another as the products of the squares of their velocities; of the squares of the sines; of the angles of incidence; and of the surfaces.

All these consequences may be deduced from the preceding principles; it only remains to apply them.

Let AB (*Plate IV. Fig. 4.*) represent the extreme breadth of a vessel, and let the fore part be formed according to the angles ACB , or AFB , or ALB . In order to find the efforts of the fluid, supposing

ing the velocity and direction to be the same, and parallel to the keel, in the three cases; upon the middle of the line AB , erect the perpendicular EL , which will pass through the tops of all the triangles; then to find the sines of the angles of incidence, with the radius AB describe two arches AF and BF to intersect one another in the vertex of the equilateral triangle; the arches will intersect the sides of the angle, that is less than 60 degrees; but not the sides of that which is more than 60 degrees, produce one of the sides from C to M (*Plate IV. Fig. 4.*) Lastly, let fall the perpendiculars MD , FE , PK , upon the line AB , from all the points where the arches intersect, either the sides of the triangles, or the sides that are produced. So shall AE , AD , and AK , represent the sines of the angles of incidence upon the different triangles AFB , ACB , and ALB .

It will be easier to observe, that the effort of the fluid upon the intire fore parts ACB , AFB , or ALB , is to the effort upon the extreme breadth, as the effort upon AC , AF , or AL , is to the effort upon AE ; but it was proved before, that the impressions received by two unequal surfaces, opposed to the direction of a current, are as the squares of the sines of the angles of incidence multiplied by the surfaces, so, in this case, the impression on AC will be to that on AE , or (which is the same thing) the impression on ACB will be to that on AB , as the square of AD , the sine of the angle of incidence multiplied by ACB , is to the square of the radius multiplied by AB .

We have also the effort on AFB to the effort on AB ; as AFB , multiplied by the square of AE , the sine of the angle of incidence, is to AB , multiplied by the square of AB the radius. This proportion would shew the effort of the fluid upon the prow AFB , in a perpendicular direction to the sides AF and BF , which would be very useful, if it were required to determine the dimensions of the timber, that is, to resist that pressure of water; but in the present case, where only the relative effort upon the prow is considered in the direction of the keel, we must form another resolution. Let then CD (*Fig. 8*) represent the effort upon FB , perpendicular to that surface, if from the point F we let fall the perpendicular DH , and compleat the parallelogram $GCDH$, CG shall represent the relative effort upon the prow in the direction of the keel, so the whole effort upon FB , may be represented by FB multiplied by the square of the angle of incidence, which is to the relative effort as FB is to EB : The relative effort then is equal to the square of the sine of the angle of incidence multiplied by EB , or by the sum of the particles which fall upon FB ; so to find the relative effort on FB , we must multiply

facing page 64.

Fig. 3.

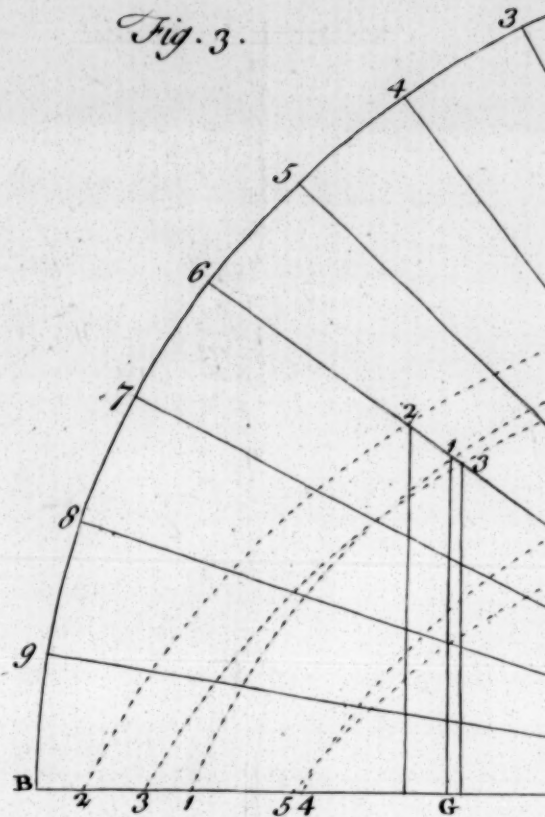
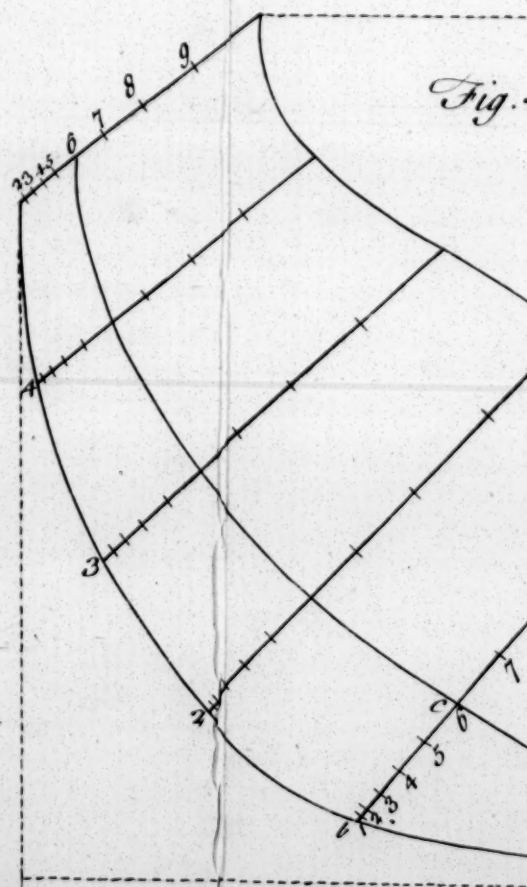
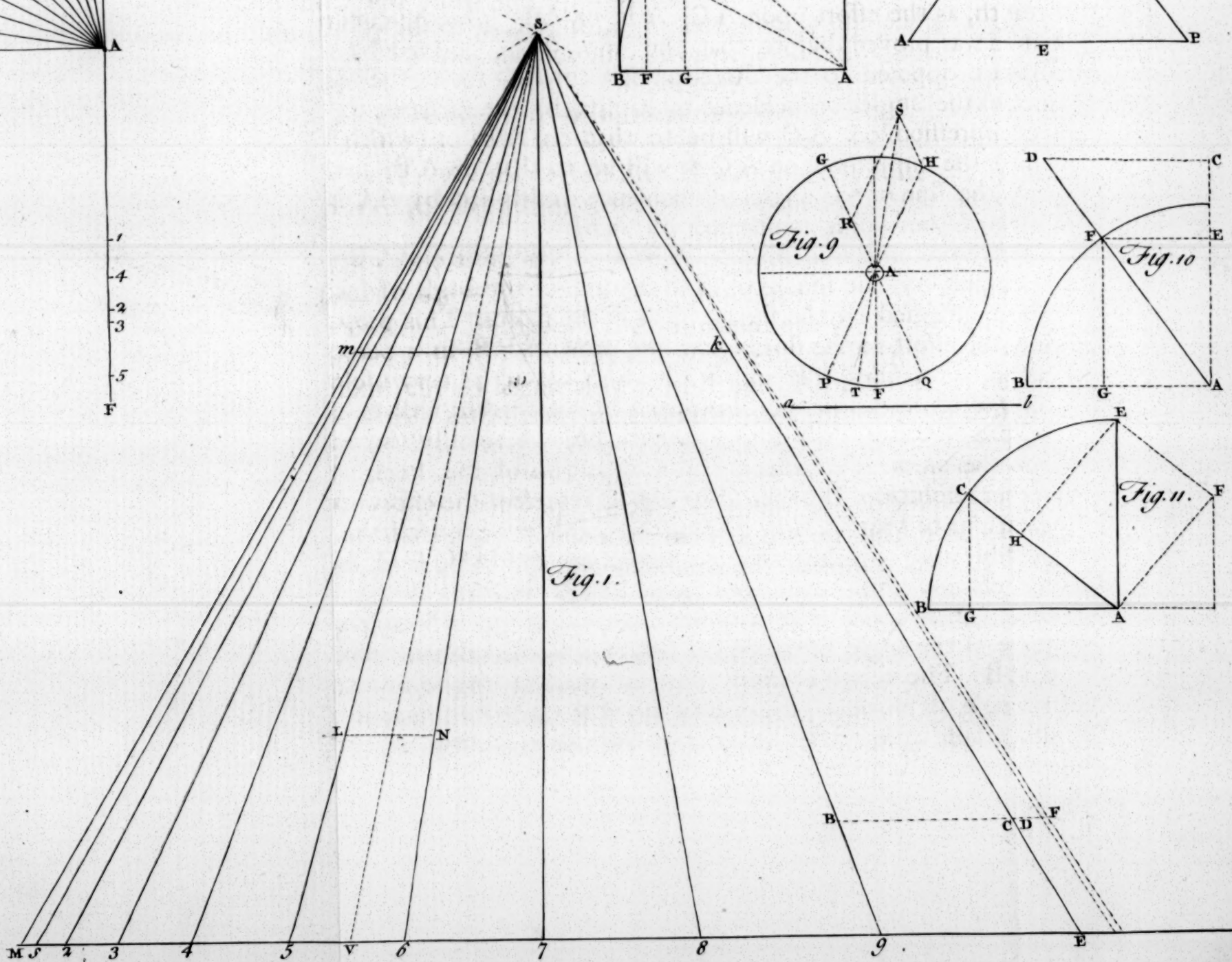
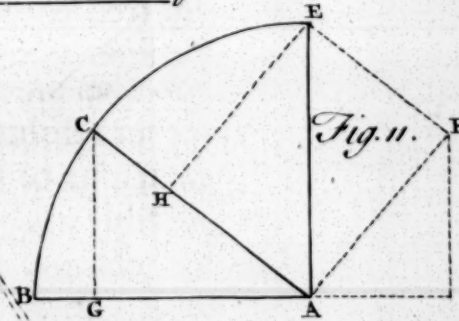
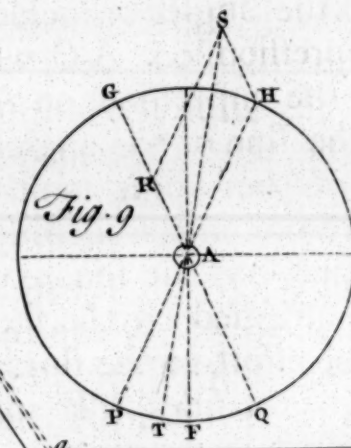
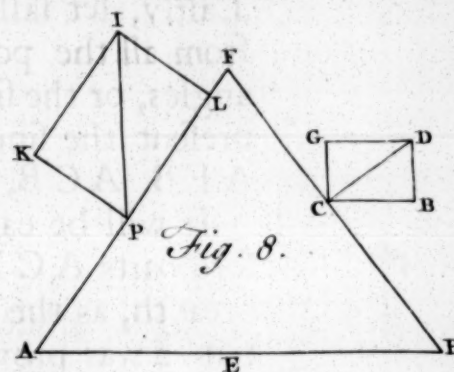
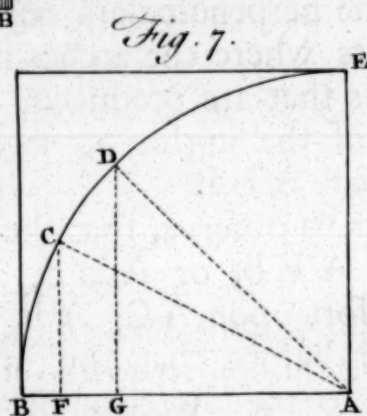
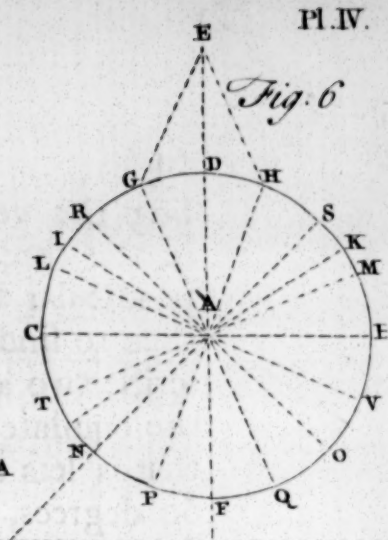
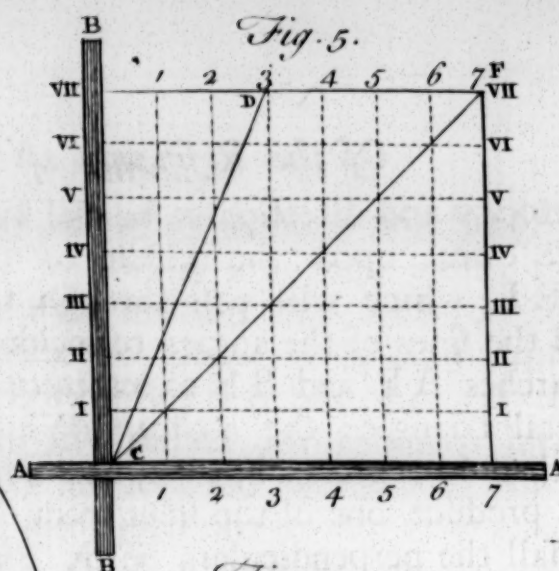
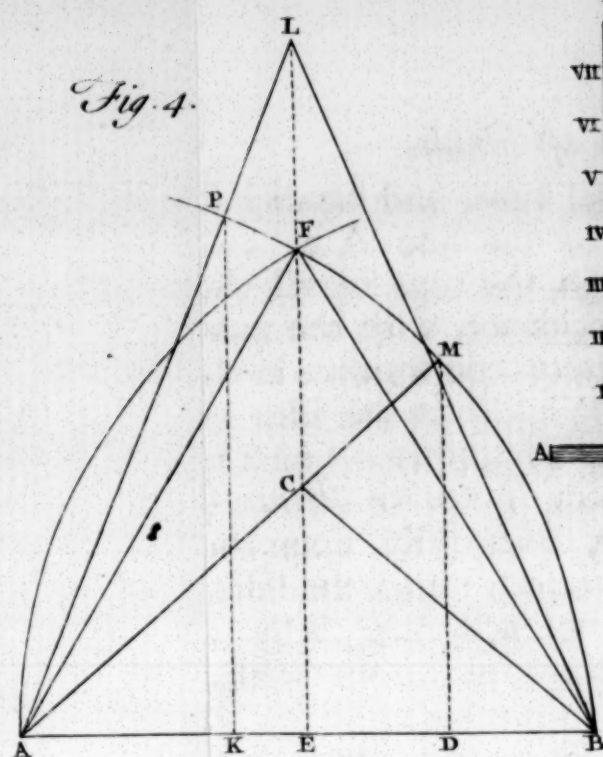
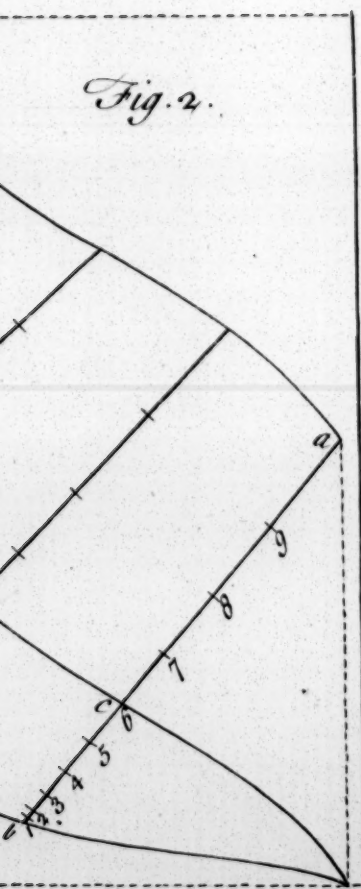
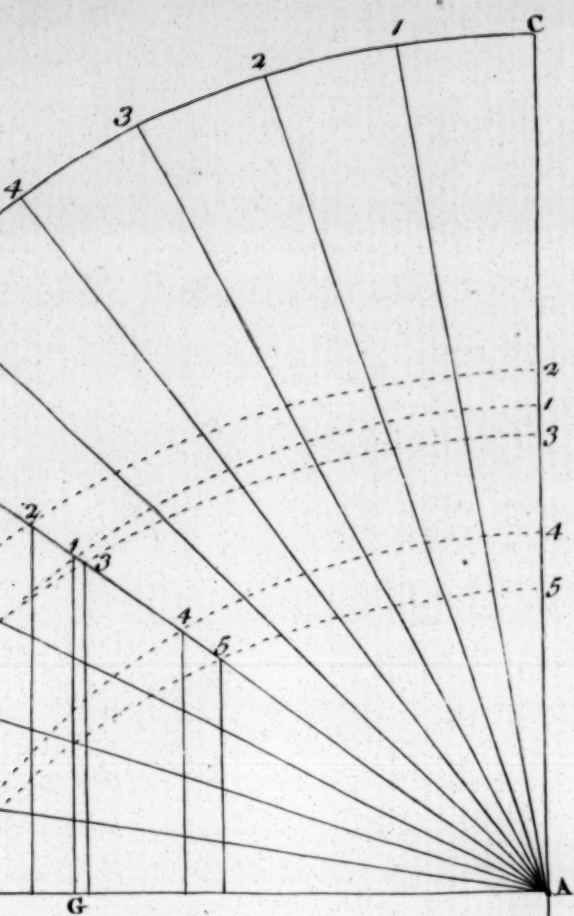


Fig.





Of the Reflection of Light

Book IX

...the plane of the angle of incidence by the projection of the
...upon the plane of the angle of incidence
The method cannot be only applied but to rectilinear rays
...by dividing a number of small parts each may be con-
sidered without any sensible error, as a straight line. M. Bouguer
...the method of the experiment of the degree of extinc-
tion of light by reflection and refraction. It is to be hoped, that
the discovery of the nature of light will be a great knowledge of the
phenomena. In that all that remains now is to apply this to the degree
of a ray of light, which has been already laid down.

...the plane of the angle of incidence by the projection of the
...upon the plane of the angle of incidence
The method cannot be only applied but to rectilinear rays
...by dividing a number of small parts each may be con-
sidered without any sensible error, as a straight line. M. Bouguer
...the method of the experiment of the degree of extinc-
tion of light by reflection and refraction. It is to be hoped, that
the discovery of the nature of light will be a great knowledge of the
phenomena. In that all that remains now is to apply this to the degree
of a ray of light, which has been already laid down.

...the plane of the angle of incidence by the projection of the
...upon the plane of the angle of incidence
The method cannot be only applied but to rectilinear rays
...by dividing a number of small parts each may be con-
sidered without any sensible error, as a straight line. M. Bouguer
...the method of the experiment of the degree of extinc-
tion of light by reflection and refraction. It is to be hoped, that
the discovery of the nature of light will be a great knowledge of the
phenomena. In that all that remains now is to apply this to the degree
of a ray of light, which has been already laid down.

...the plane of the angle of incidence by the projection of the
...upon the plane of the angle of incidence
The method cannot be only applied but to rectilinear rays
...by dividing a number of small parts each may be con-
sidered without any sensible error, as a straight line. M. Bouguer
...the method of the experiment of the degree of extinc-
tion of light by reflection and refraction. It is to be hoped, that
the discovery of the nature of light will be a great knowledge of the
phenomena. In that all that remains now is to apply this to the degree
of a ray of light, which has been already laid down.

...the plane of the angle of incidence by the projection of the
...upon the plane of the angle of incidence
The method cannot be only applied but to rectilinear rays
...by dividing a number of small parts each may be con-
sidered without any sensible error, as a straight line. M. Bouguer
...the method of the experiment of the degree of extinc-
tion of light by reflection and refraction. It is to be hoped, that
the discovery of the nature of light will be a great knowledge of the
phenomena. In that all that remains now is to apply this to the degree
of a ray of light, which has been already laid down.

...the plane of the angle of incidence by the projection of the
...upon the plane of the angle of incidence
The method cannot be only applied but to rectilinear rays
...by dividing a number of small parts each may be con-
sidered without any sensible error, as a straight line. M. Bouguer
...the method of the experiment of the degree of extinc-
tion of light by reflection and refraction. It is to be hoped, that
the discovery of the nature of light will be a great knowledge of the
phenomena. In that all that remains now is to apply this to the degree
of a ray of light, which has been already laid down.

multiply the square of the angle of incidence by the projection of the plane FB upon the beam EB .

Tho' this method cannot be truly applied but to rectilineal triangles, yet, by dividing curves into a number of small parts, each may be considered, without any sensible error, as a strait line. *M. Bouguer* makes use of this method of approximation to a sufficient degree of exactness. What we have already said upon that head, it is to be hoped, will facilitate this description to such as have only a slight knowledge of the mathematics; so that all that remains now is to apply this to the draught of a ship of 70 guns, which has been already laid down.

A Calculation of the Resistance of a Fluid upon the Prow of the ship of 70 Guns, which we have laid down in a draught compared with the Effort of the same Fluid upon the Area of the Midship Frame.

As the operations are to be performed upon the plane of projection before laid down, all the frames in the fore part must be exactly formed as before in *Plate II.* in order to which it will be necessary to make use of a larger scale, as in *Plate V.*

It will be very convenient to draw the water lines $I, II, III, \&c.$ and the frames $1, 2, 3, \&c.$ to the midship frame at equal distances from one another.

It is plain, that the water lines and frames divide the prow into trapezia, such as $ra, 8b, 7c, \&c.$ corresponding to the trapezium ab , and parallelogram ad in the plane of elevation *Plate II.*

It will be necessary to observe, that there must be so many water lines and frames that the lines $8a, 7b, 6c, \&c.$ which are curves, may be esteemed strait lines.

We must draw the diagonals $ra, 8b, 7c, \&c.$ through the trapezia; but we may take two trapezia at once near to the midships, because the ships sides are there nearly parallel to the current.

It will likewise be proper to observe that these diagonals are the projections of the diagonals of the parallelograms represented upon the plane of elevation, at least, on the surface of the ship; as for instance, the diagonal $8b$, on the plane of the projection, is the projection of the diagonal $8d$ drawn on the plane of elevation.

These diagonals divide the prow into the triangles $1, 2, 3, 4, \&c.$ which strike the fluid with different degrees of obliquity.

We have not the entire areas of these triangles, by reason of the curving of the prow, but only their projection on the midship frame; but this is all we want, for the sum of all the particles of water that strike the tri-

angles are proportioned to the triangle projected on the midship frame, since the water that ranges along each triangle may be considered as a triangular prism, the base of which is equal to the triangle $ra8$, *Fig. 1*, *Plate V*. and this was the thing in question. Mr. *Bouguer* proposes to calculate the effort of the fluid on each triangle, their sum will give the shock of the water upon the whole prow, and compare this to the shock of the fluid upon a surface parallel to the area of the midship frame.

To attain this Mr. *Bouguer* lets fall perpendiculars to every frame, from the angles formed at the intersection of the water lines and the diagonals that were drawn to form the triangle; for instance, upon the frame 8, the perpendiculars lb and rp ; upon the frame 7 8, the perpendicular $8m$ on one side, and the perpendicular nc on the other side; &c.

This method requires that there be as many right angled triangles formed as there are triangles on the prow, and as there must be a great number of them, it will be necessary to find some method of forming them. The following seems to me to be the most expeditious.

Draw two parallel lines BD and CR ; let the distance betwixt them be equal to that betwixt the frames on the plane of elevation, and by this one operation we have the height of all the triangles that are contained betwixt the parallels.

As the base of all the rectangles should be equal to the perpendicular of the corresponding triangle of the prow, we may set off the length of each perpendicular upon the parallel CR ; so shall CH *Fig. 2*, be equal to rp , *Fig. 1*; HL , *Fig. 2*, equal to sa , *Fig. 1*; LE equal to $8M$, &c. to compleat the triangles, draw the perpendiculars HN , LM , and the hypotenuses DH , NL , &c.

If one of these rectangles be considered singly, DH may represent the radius, and CH will be the sine of the angle of incidence.

All these triangles being described, we may begin to find their areas on the plane of the projection, because it is upon this that the relative impulse in the direction of the keel depends, which is the thing now required, as was before observed.

The surface of a triangle is found by multiplying half the base by the perpendicular, so the surface of the triangle $r, a, 8$, will be the product of the perpendicular rp , (equal to CH) multiplied by half the base $a8$, and this will be the sum of all the particles which strike the triangle $r, a, 8$, which is an element of the prow of the ship.

In order to find the relative force of the fluid in the direction of the keel on that part of the bottom corresponding to the triangle $r, a, 8$, it is only

only multiplying the surface of the triangle by the square of the sine of the incidence; in place of multiplying it by the square of the radius, which would give the impulse the triangle would receive from the water in a perpendicular direction; now if we divide this impulse by the oblique one, the quotient will give the quantity that the impulse is diminished by the obliquity of the prow; but there will be no occasion for this last step, for as the sum of all the products of the triangles multiplied by the square of the radius, gives the effort of the fluid upon the midship frame; the direct effort may be found by multiplying the area of the midship frame by the square of the radius, and if this be divided by the sum of the products of all the triangles multiplied by the squares of the sines of the angles of incidence on each triangle, we shall know the diminution of the resistance which the prow meets with in proportion to that of the midship frame.

It would be almost impracticable to multiply the surface of each triangle by the square of the sine of the angle of incidence, upon which account Mr *Bouguer* substituted proportional lines in place of the squares of the sines, which we shall now explain.

It was before observed, that if DH be the radius, CH will be the sine of the angle of incidence.

If we let fall the perpendicular CO upon the line DH , we shall have the triangle DCH similar to DOC ; so taking the equal lines CD , and NH for the radius, CO will be the sine of the angle of incidence.

If we draw OP perpendicular to DC , the triangles DOC and COP will be similar, therefore the triangles DCH and COP will be similar, and DH is to CH as OC to CP ; but DH is to CH as DC to CO , and by multiplying these two proportions, the square of DH will be to the square CH as DC is to PC ; that is, if DC represent the square of the radius, PC will be the square of the sine of the angle of incidence CDH . So the lines CP , HQ , LG , &c. give the squares of the sines of the angles of incidence in the triangles 1, 2, 3, &c. which are to be multiplied by the surfaces of the triangles; and the parallels DC , NH , &c. always represent the radius.

A Calculation of the Resistance of the Fluid upon the Prow of a Ship of 70 Guns, compared with that upon the Midship Frame.

Triangles.	Perpendi- cular.			Multiply- ed by half the base.			Product.				Multiply- ed by the square of the sine of the angle of incidence.			Product gives the effort of the water up- on the trian- gle.			
ft.	f.	in.	lin.	f.	in.	lin.	f.	in.	lin.	poi.	f.	in.	lin.	f.	in.	lin.	poi.
1	6	6	0	1	9	6	11	7	9	0	3	2	0	36	10	6	6
2	5	7	6	1	6	3	8	6	7	10	2	8	0	22	9	9	0
3	4	6	6	1	9	6	8	1	7	9	1	11	6	15	11	2	8
4	4	6	6	1	9	6	8	1	7	9	1	11	6	15	11	2	8
5	2	9	6	1	8	6	4	9	2	9	0	11	0	4	4	5	6
6	2	8	0	1	9	6	4	9	4	0	0	9	0	3	7	0	0
7	1	11	6	1	7	6	3	2	2	3	0	5	0	1	3	10	11
8	2	2	0	1	9	0	3	9	6	0	0	6	6	2	0	7	9
9	1	4	0	1	7	6	2	2	0	0	0	2	6	0	5	5	0
10	1	4	0	1	7	6	2	2	0	0	0	2	6	0	5	5	0
11	0	5	0	1	6	6	0	7	8	6	0	1	0	0	0	7	8
12	0	10	0	1	7	6	1	4	3	0	0	2	0	0	2	8	6
13	0	2	6	1	6	6	0	3	10	3	0	0	8	0	0	2	6
14	0	4	0	1	6	6	0	6	2	0	0	1	2	0	0	7	2
15	0	1	0	1	6	6	0	1	6	6	0	0	3	0	0	0	4
16	0	5	0	1	6	6	0	7	8	6	0	1	6	0	0	11	6

The total effort of the first piece r V

Of the second

Of the third

Of the fourth

Of the fifth

Of the sixth

104 2 8 8

57 10 6 2

43 8 6 5

28 0 8 10

12 9 8 7

3 2 8 11

Total 249 10 11 7

We must in the next place find the direct effort of the water upon the area of the midship frame, by multiplying the area by the square of the radius.

OPE-

O P E R A T I O N.

Half the 6th water line r VI	19	2	0
The whole 5th water line V	20	0	0
The 4th water line	19	5	0
The 3d water line	18	1	0
The 2d water line	15	11	6
The 1st water line	12	0	0
The breadth of the keel	0	0	0
Total	95	9	6
Multiplied by the distance betwixt the water lines, which is	3	2	0
Product is the area of the midship frame	303	4	1
Multiplied by the distance betwixt the frames	8	0	0
Product	2426	8	8

This being divided by $249 : 10 : 11$, the sum of the efforts of the fluid upon the triangles of the prow; the quotient is $9 \frac{7}{10}$, which shews that the effort of the fluid upon the prow is to that upon the midship frame as 1 is to $9 \frac{7}{10}$, which is a sufficient diminution of the resistance for a ship of this force. Hence we may conclude that the water lines in the fore-body are well formed, but a frigate will require more diminution, as will appear by the following examples.

The *Brillant*, as $3 \frac{1}{2}$ to 1, a very bad failer.

The *Tigre*, as 5 to 1, a company keeper.

A ship of 50 guns, designed by M. *Boyer*, but not built, as 8 to 1.

The *Monarque*, of 74 guns, built by M. *Ollivier* in 1745, as $9 \frac{1}{2}$ to 1.

The *Palme*, of 12 guns, 4 lb. shot, built by M. *Ollivier* in 1744, as $13 \frac{1}{2}$ to 1.

The *Alcid*, of 64 guns, by Mr *Ollivier*, at *Brest* 1741, as $6 \frac{1}{4}$ to 1.

The *Renomme*, built at *Brest* by Mr *Desalieurs* 1744, as 10 to 1.—this ship, by the account of the captians, was a very fine failer.

The *Badine*, 6 guns of 3 lb. shot, as $7 \frac{1}{4}$ to 1.

The *Panthere*, of 20 guns, 6 lb. shot, as $10 \frac{1}{2}$ to 1.

The *Amazon*, of 44 guns, built by M. *Blaise Pengalot*, as $8 \frac{3}{5}$ to 1.

The *Superbe*, built by M. *Helie*, as $5 \frac{2}{10}$ to 1.

The *Mutine*, of 24 guns, built by M. *Geffroi*, senior, as $10 \frac{3}{5}$ to 1.

We have compared the efforts of the fluid upon the prow of each ship, with that upon a plane, equal to the area of the midship frame.

It will be proper also to examine if the resistance in those be less than in ships which are known to be good failers; but it may happen that a ship,

ship, whose midship frame has a small area, may meet with little resistance, tho' her prow be not diminished in proportion to that of her midship frame; so it will not be sufficient to know this proportion only, to be assured whether or not the ship will be a fine sailer. We must also compare the areas of the midship frames, and not rest satisfied with comparing the efforts of the fluid; upon the prow of the ship we have laid down, with that upon the prow of a ship of the same rate, which has gained a good character.

The first Example of Comparison.

We know that the area of the midship frame of the 70 gun ship, we have laid down, is $606 : 8 : 2$, and that the effort of the fluid upon the prow is to that on the midship frame as 1 is to $9\frac{7}{10}$. Now if another ship of the same rate has the area of her midship frame 7 or 800 feet, supposing the sails, and every thing that may contribute to sailing, to be alike in both; it is plain this last cannot sail so well as that we have laid down, and by this example, it is very plain, that if we would calculate which of two ships would sail best, we must, after finding how much the resistance of the fluid upon the midship frame of each is diminished by the form of their prows; also compare the areas of their midship frames; that we may know which of the two has the greatest mass of water to displace; but if it was only required to know, which of two ships of the same rate would sail best, it would be sufficient to compare the efforts of fluids upon their prows.

The second Example of Comparison.

We have found by the calculation, that the effort of the fluid upon the prow of our ship of 70 guns, is $249 : 10 : 11 : 7$; but if by a like calculation we find the resistance upon the prow of a ship of the same force, and carrying the same quantity of sail, to be 300 feet, we may thence conclude that ours will sail best.

It will be proper to examine, by the same calculation, whether the ship we have laid down, can carry a good sail, drive but little to the leeward, and steer well; but as this treatise has already exceeded the bounds I proposed, I am forced to confine myself to the two preceding conditions, which are the most important. The methods to find the other qualities of the ships we lay down, may be found in Mr Bouguer's treatise.

F I N I S.



refif-
mid-
y, to
also
com-
e laid
n has

we
the
other
feet,
to be
laid
ulate
the
d by
mes,
er to
f the
rts of

in the
calcu-
force,
uence

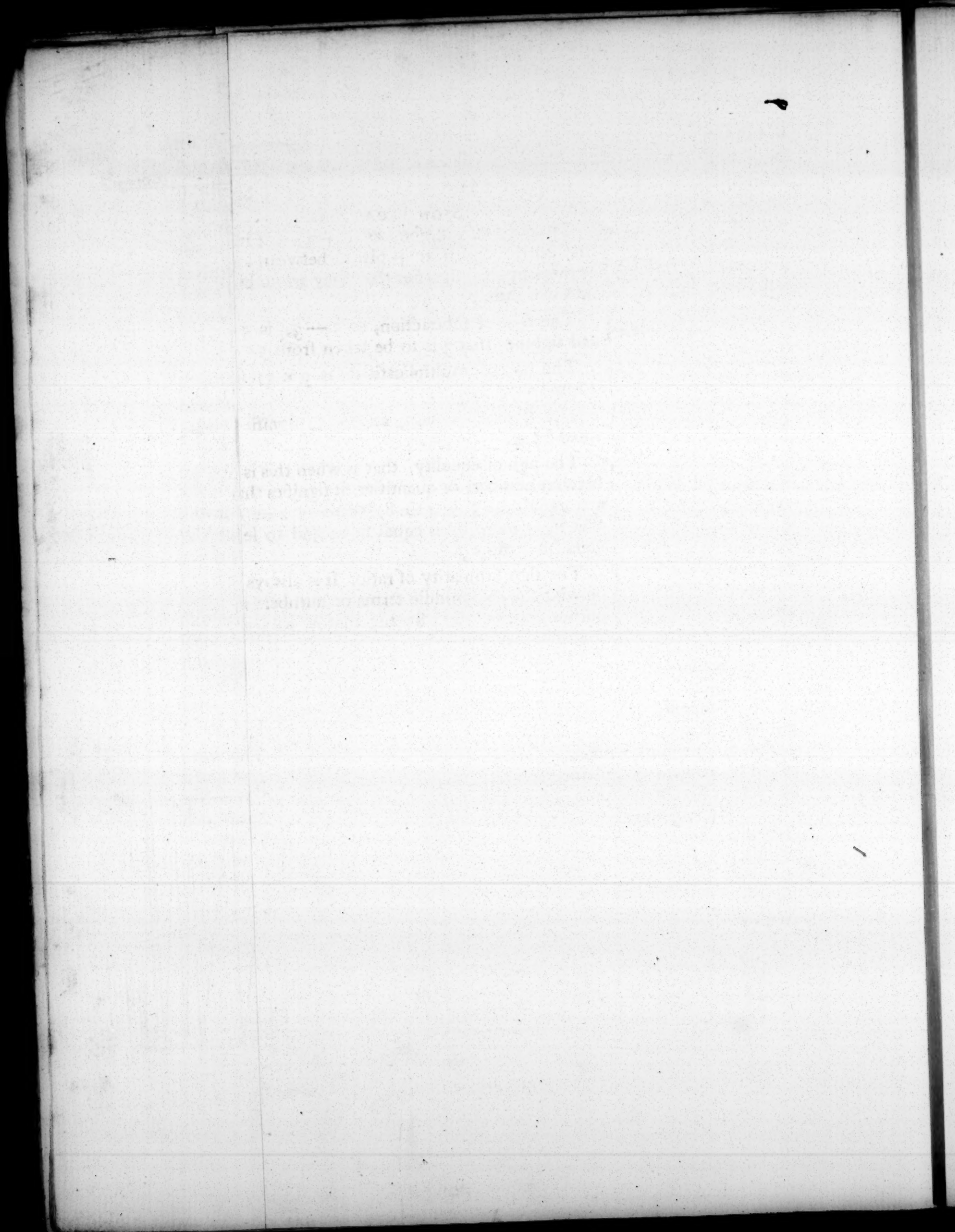
ship
ward,
pro-
tions,
lities

Append p. 70.

Fig. 1.

Fig. 2.

Append p. 70.



*An EXPLICATION of the SIGNS or CHARACTERS made use of in this
TREATISE.*

SIGNS.	NAMES.	SIGNIFICATIONS.
+	Plus, or more.	The sign of addition, as $3 + 5$, is 3 more 5, that is, the character $+$ placed between any two or more figures, signifies that they are to be added into one sum.
-	Minus, or less	The sign of subtraction, as $5 - 3$, is 5 less 3, and signifies that 3 is to be taken from 5.
x	Multiplied by	The sign of multiplication, as 5×3 , signifies 5 multiplied by 3.
÷	Divided by	The sign of division, as $8 \div 4$, signifies 8 divided by 4.
=	Equal to	The sign of equality, that is when this is placed betwixt numbers or quantities, it signifies that they are equal. as $5 + 3 = 8$, or $10 - 2 = 5 + 3$, that is, 5 more 3, is equal to 8, and 10 less 2, is equal to 5 more 3.
::	So is	The sign simularity of ratio. It is always placed betwixt the two middle terms or numbers in proportion, thus $3 : 9 :: 8 : 24$, that is, as 3 is to 9, so is 8 to 24.

R. Radius.
 S. Sine.
 T. Tangent,
 Sec. Secant.
 S. c. Sine complement.
 T. c. tangent complement.
 Sec. c. Secant complement.
 H. Hypothenufe.
 B. Base.
 P. Perpendicular.

E R R A T A.

Page	Line	for	read
14	19	a in	in a
25	15	of division	in the divisions
26	31	$f B$	$f b$
30	Margin	Fig. 25	Fig. 25 at Prop. VIII.
30	30	$C f e$	$C f E$
35	13	from the point N, &c.	cancel
38	Margin	Fig. 5.	cancel
40	Margin	Plate II.	Plate I. Fig. 37.
40	Margin	Fig. 1.	Plate II. Fig. 1.
41	Margin	Fig. 6, 7, 8, 9, 10.	cancel
41	30	Example	Examples
43	Margin	Fig. 30.	cancel
49	4	40	50
49	10	50	40
49	13	base at A . . . also for 50	base ; at A read 40
53	15	$T x = x E$	$T x = x F$
53	18	$m, s, n, t,$	$m s, n t,$
53	34	$F D$	$F d$
56	17	the	then
56	27	$r t \frac{1}{2} r s$	$r t \times \frac{1}{2} r s$
58	12	1.14592	3.14592
58	31	.785	.785
59	5	whose diame-	whose diameter is 1.
59	30	line, as	line
64	11	$C m$	$C s$
64	12	$m s \times C +$	$m s \times C t$
64	21	$C s$	$C s$
64	21	including the areas	including half the areas
68	Margin		before Case 2d. prefix Fig. 53
82	Margin	Plate I.	Plate II.
82	17	5.9990	5.6990
102	Column 8	Length	Depth
103	22	as in the columns	cancel
104	7	6.25	.625
105	2	height	length
105	16	double line ; on the rule	double line on the rule ; look
106	21	11,	1, 1,
106	22	11,	1, 1,
106	last line	A C	A D
110	31	$f o B$	$t o B$
111	4	Fig. 2.	Fig. 9.
111	5	S S	S S Fig. 2.
114	5	remarked	marked
121	36	1 s, 2 e, 3 b,	1 r, 2 d, 3 a.
122	34	G A E	C A E
124	2 and 3	provided the dimensions and inclination of these planes to one another be given.	cancel
126	32	s q c b	s q 7

ERRATA.

Page	Line	for	read
130	18	the body	the body plane
131	16	ribband lines	ribbands
133	after line 22	add	See Plate VII. where the curves here defined are distinguished by their initial letters.
136	36	M to y	M to S
137	37	C	c
138	19	BEND	Bend Mould
138	26	H lw	Hollow mould
144	20	floor	floor timbers
152	10	so	fo
162	29	bl	bl
168	40	when this is	cancel
169	1	hewed of	cancel
169	1	of the outside	(in that direction)
199	8	+ .697997	+ .697997
201	17	56° 15'	56° 15' to 33° 45'
204	4	ftance	distance
214	11	Eo: En	En: Eo
217	1	50	15
218	16	Cx	CX
225	5	Long line	Log line
225	17	AB	AC
225	18	BE	AE
228	31	difference of R	difference of latitude; R.
231	7	by 3 15	cancel
237	4	north	south
244	24	65338	65338
244	25	18668	18688
249	6	27° 2' R: difference of latitude	27° 2' R: difference of latitude 1063:
249	7	distance: 1191	distance 1191
249	14	2.738920	2.739030
249	28	75.7	75.5
249	29	18.4	21.1
249	30	546.9	549.6
250	35	fide	fine
253	10	30	60
253	11	60	30
253	33	25	15
254	1	25	15
254	2	15	25
254	6	15	25
256	4	Pp	PP
256	6	Pp	PP
258	12	transcribe	transcribes
258	34	make	makes

E R R A T A.

Page	Line	for	read
14	19	a in	in a
25	15	of division	in the divisions
26	31	$f B$	$f b$
30	Margin	Fig. 25	Fig. 25 at Prop. VIII.
30	30	$C f e$	$C f E$
35	13	from the point N, &c.	cancel
38	Margin	Fig. 5.	cancel
40	Margin	Plate II.	Plate I. Fig. 37.
40	Margin	Fig. 1.	Plate II. Fig. 1.
41	Margin	Fig 6, 7, 8, 9, 10.	cancel
41	30	Example	Examples
43	Margin	Fig. 30.	cancel
49	4	40	50
49	10	50	40
49	13	base at A . . . also for 50	base ; at A read 40
53	15	$T x = x E$	$T x = x F$
53	18	$m, s, n, t,$	$m s, n t,$
53	34	$F D$	$F d$
56	17	the	then
56	27	$r t \frac{1}{2} r s$	$r t x \frac{1}{2} r s$
58	12	1.14592	3.14592
58	31	.785	.785
59	5	whose diame-	whose diameter is 1.
59	30	line, as	line
64	11	$C m$	$C s$
64	12	$m s \times C +$ $C s$	$m s \times C t$ $C s$
64	21	including the areas	including half the areas
68	Margin		before Case 2d. prefix Fig. 53
82	Margin	Plate I.	Plate II.
82	17	5.9990	5.6990
102	Column 8	Length	Depth
103	22	as in the columns	cancel
104	7	6.25	.625
105	2	height	length
105	16	double line ; on the rule	double line on the rule ; look
106	21	11,	1, 1,
106	22	11,	1, 1,
106	last line	$A C$	$A D$
110	31	$f o B$	$t o B$
111	4	Fig. 2.	Fig. 9.
111	5	$S S$	$S S$ Fig. 2.
114	5	remarked	marked
121	36	$1 s, 2 e, 3 b,$	$1 r, 2 d, 3 a.$
122	34	$G A E$	$C A E$
		provided the dimensions	
124	2 and 3	and inclination of these	cancel
		planes to one another be	
		given.	
126	32	$s q c b$	$s q 7$

ERRATA.

Page	Line	for	read
130	18	the body	the body plane
131	16	ribband lines	ribbands
133	after line 22	add	See Plate VII. where the curves here defined are distinguished by their initial letters.
136	36	M to y	M to S
137	37	C	c
138	19	BEND	Bend Mould
138	26	H lw	Hollow mould
144	20	floor	floor timbers
152	10	so	so
162	29	bl	bl
168	40	when this is	cancel
169	1	hewed of	cancel
169	1	of the outside	(in that direction)
199	8	+1.697997	+1.697997
201	17	56° 15'	56° 15' to 33° 45'
204	4	ftance	distance
214	11	Eo: En	En: Eo
217	1	50	15
218	16	Cx	CX
225	5	Long line	Log line
225	17	AB	AC
225	18	BE	AE
228	31	difference of R	difference of latitude; R.
231	7	by 3 15	cancel
237	4	north	south
244	24	65338	65338
244	25	18668	18688
249	6	27° 2' R: difference of latitude	27° 2' R: difference of latitude 1063:
249	7	distance: 1191	distance 1191
249	14	2.738920	2.739030
249	28	75.7	75.5
249	29	18.4	21.1
249	30	546.9	549.6
250	35	fide	fine
253	10	30	60
253	11	60	30
253	33	25	15
254	1	25	15
254	2	15	25
254	6	15	25
256	4	Pp	PP
256	6	Pp	PP
258	12	transcribe	transcribes
258	34	make	makes

ERRATA to the APPENDIX.

Page	Line	for	read
18	22	of D-	D
22	33	d and K*	d and S
22	35	to s	to l
22	36	s and l	s and l
23	5	d also for d x	b read b x
27	7	point X	point x
27	14	RS	R
27	17	point X	point x
35	26	lines	line
37	26	N L	N L
38	17	HP	H p
40	23	S	s
42	10	from N	strike it out
43	27	3d from l	3d from i
44	20	2 x	2 x
54	17	2 x + 1 x S + A B	2 x + X S x A B
62	25	Plate IV. Fig II.	Plate IV. Fig. II.
62	line 32	add	and the other perpendicular to it whose force and direction is represented by the line E H.

Where the References to the Plates are omitted in Part II. See Plate VII. and in the Appendix, See Plate 2.

